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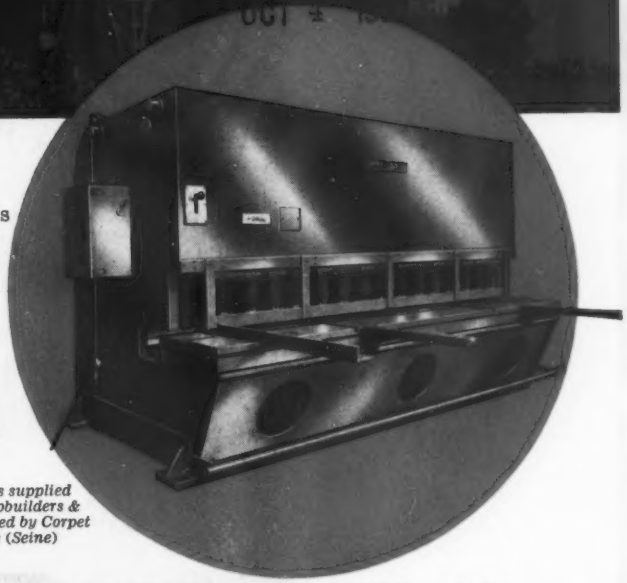

The Corpet Louvet Hydraulic Guillotine utilises the unique Gautron System of Bevel-Shearing which has many advantages over conventional methods. Both square Shearing and Bevelling is carried out in ONE CONTINUOUS OPERATION permitting increased output by obviating double handling of material and cutting setting times by half.
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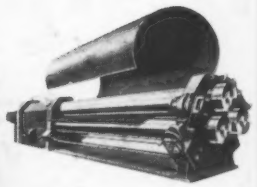

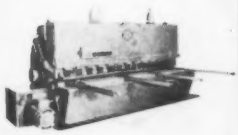

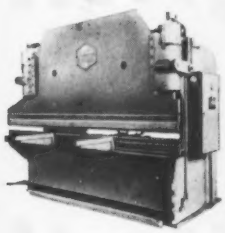

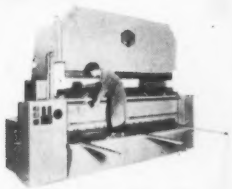

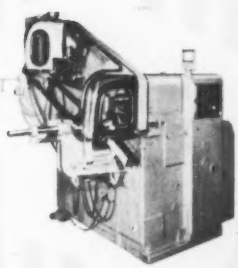

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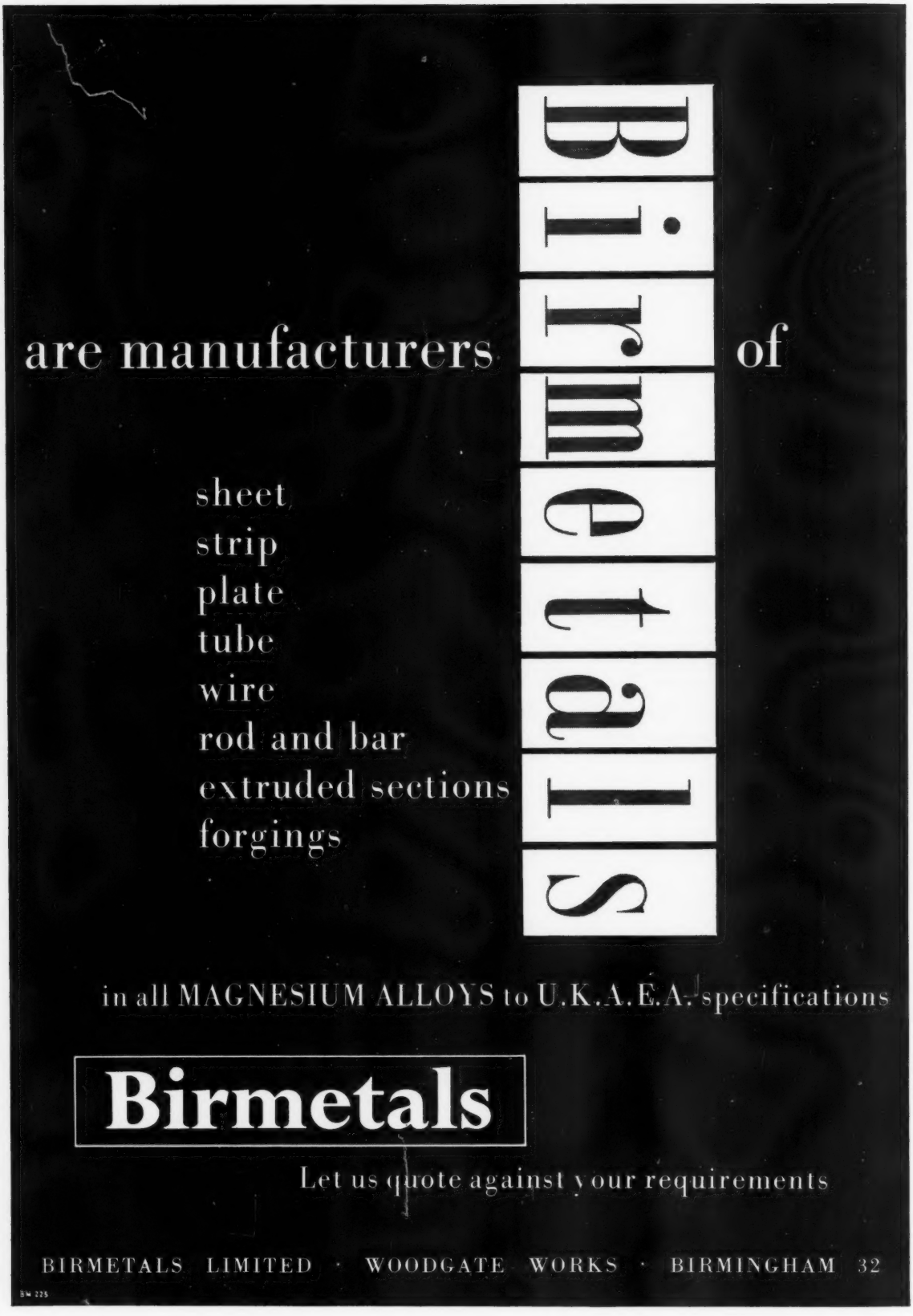
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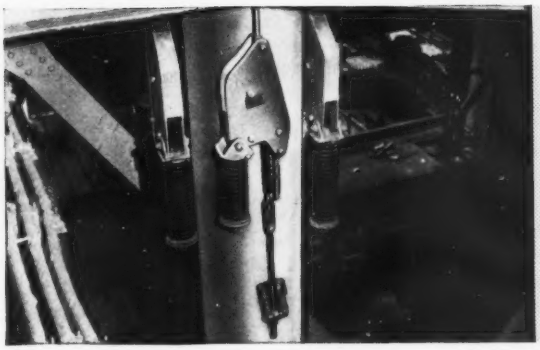

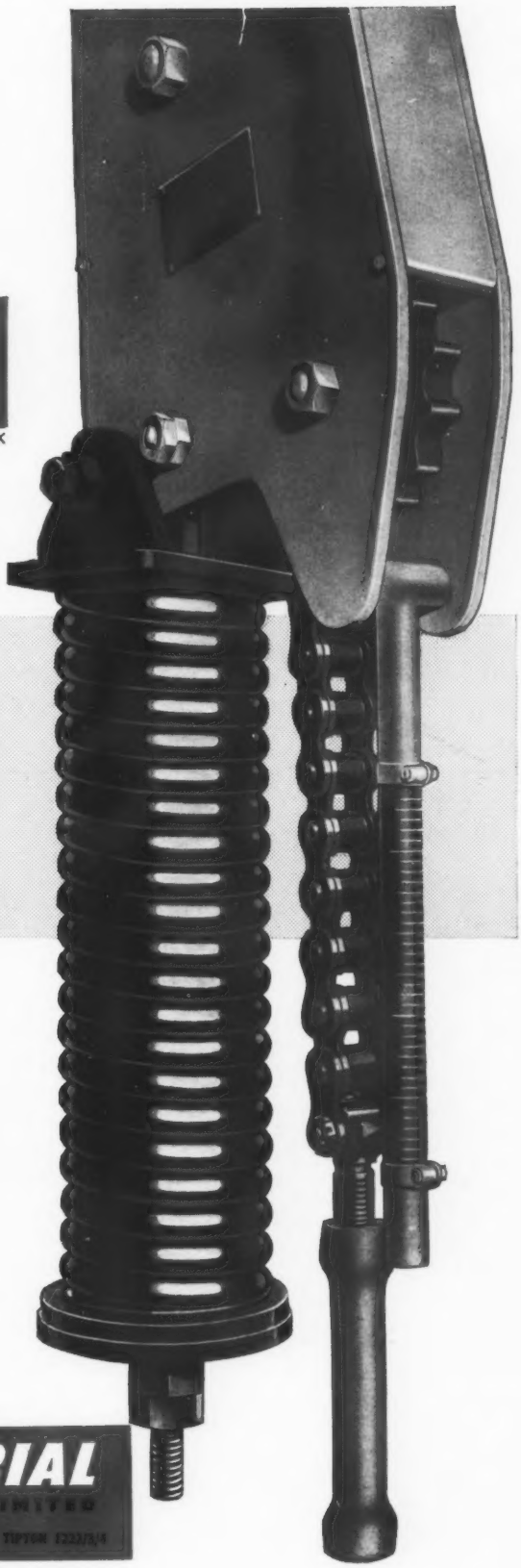

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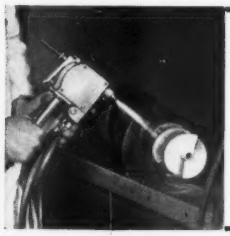

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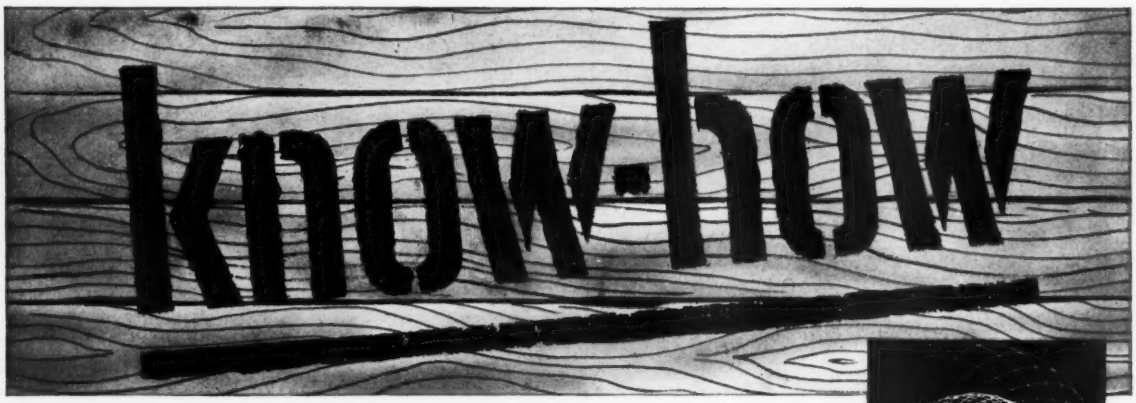

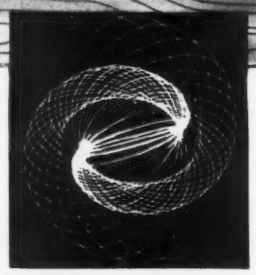

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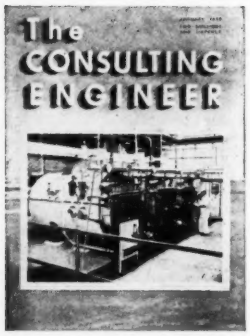

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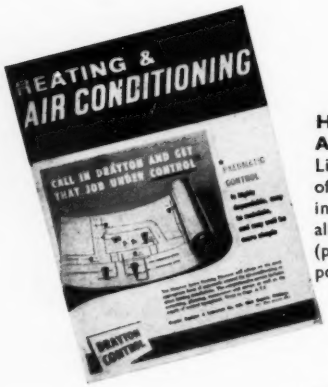

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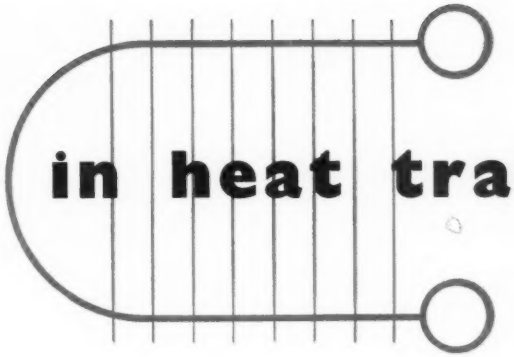

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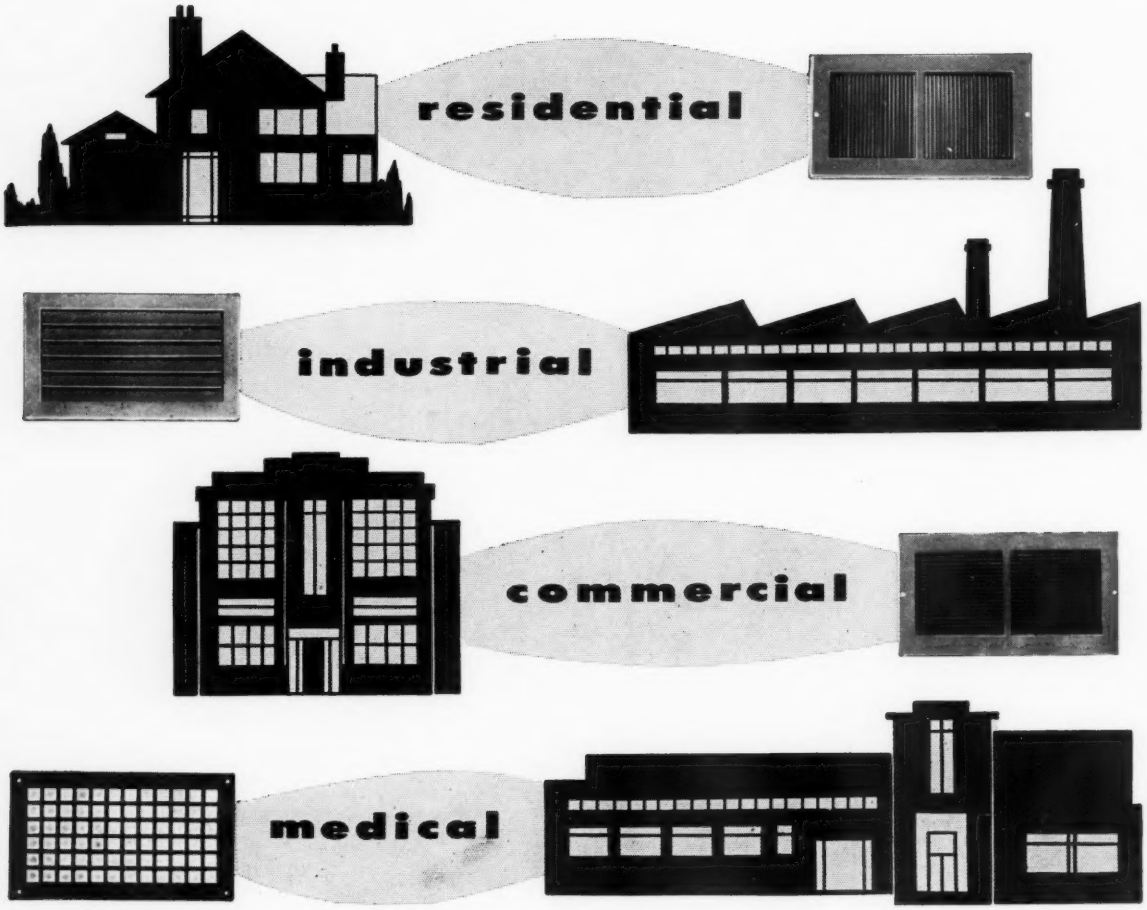

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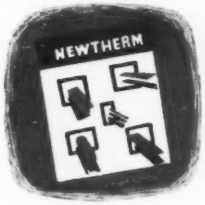

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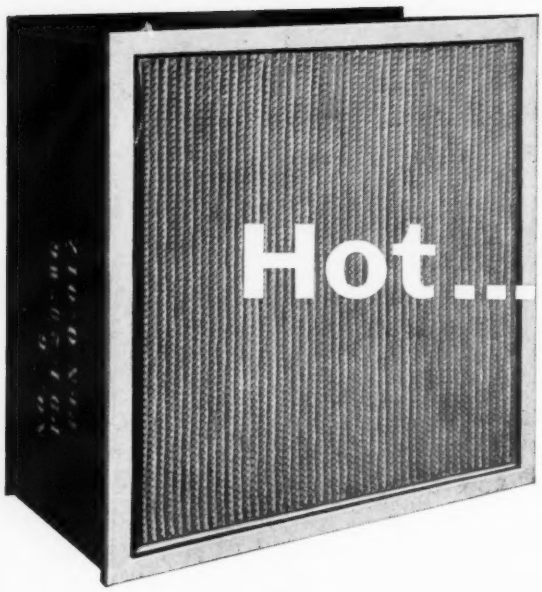

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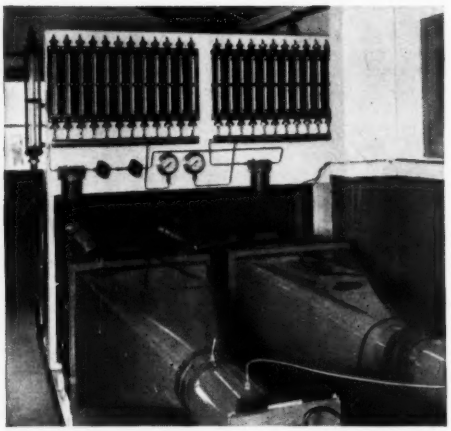
Vokes high temperature 'Absolute' filters



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Now, after five and a half years' research, a team from the Abingdon Laboratories of Esso Research Ltd., has provided the answer.

Working closely with the scientists and engineers of the Central Electricity Generating Board's Atomic Power Division and the five consortia tendering for the new nuclear power station at Trawsfynydd, in Snowdonia, this team has developed a new range of lubricants, called Essotron oils and Cosmos greases, which are resistant to radiation, heat and gas.

And Esso have proved conclusively, in practical tests, that these lubricants will remain one hundred per cent reliable, even in the vital control machinery at Trawsfynydd, for the necessary length of time. As a result, the sole contract for the supply of all lubricants to Trawsfynydd, which will be one of the two biggest nuclear power stations in the world, has been awarded to Esso.

To the authorities concerned, however, this contract is much more than a reward for successful research. It is a means of ensuring that Esso's vast technical resources will always be available to study and meet the demands of the new reactor when it is in operation.

In other words, the C.E.G.B., the U.K.A.E.A. and Atomic Power Constructions Ltd., who have won the main Trawsfynydd contract, have proved, as hundreds of smaller organisations in less dramatic industries prove every year, that it pays not only to consult Esso, but to go on consulting them. If your firm has a lubrication problem this fact applies equally to you.

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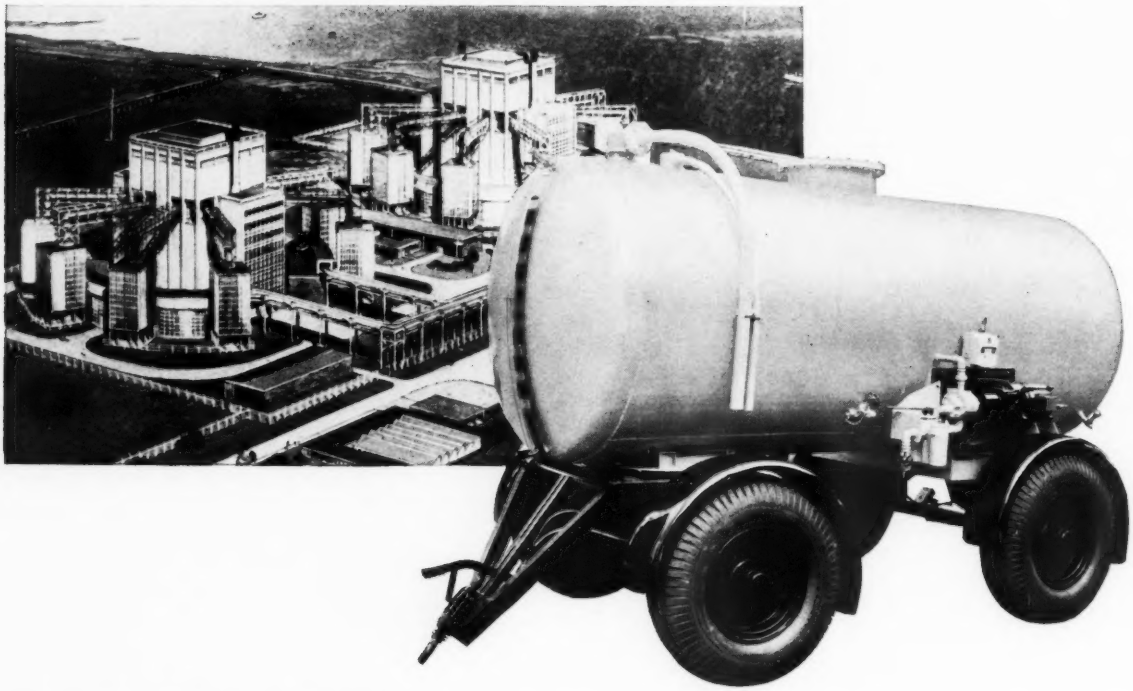

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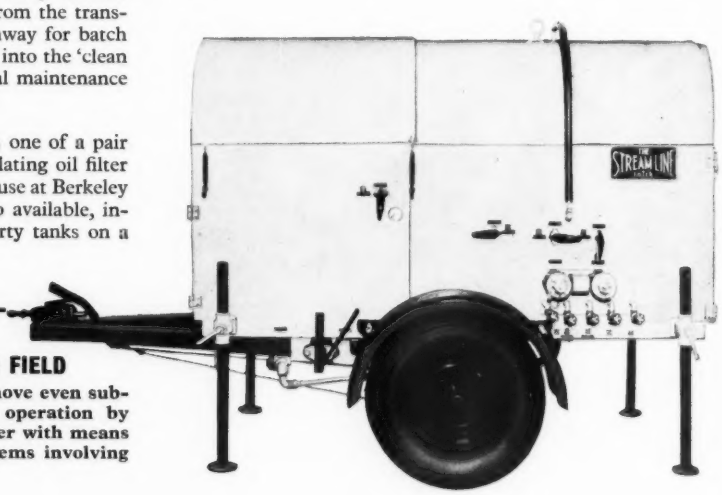

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NUCLEAR ENERGY

COMMENT

REGULAR readers of NUCLEAR ENERGY will notice some changes in this month's issue. There are for instance, extra editorial pages. The style of some of the regular items has been altered and, of course, this page of comment is new. More important, however, is the introduction of a section devoted exclusively to the subject of radioisotopes.

Although isotopes are already in widespread use both in industry and research, they are a comparatively new tool. As yet only a small portion of their potential has been tapped. The possibilities of their exploitation are endless. New applications are continually being found and developed and sometimes a new radiochemical is made, opening up even further possibilities.

It will be one of the aims of " Isotope World," the title of our new section, to keep readers informed of these developments and potentialities.

Apart from new and future users of radioisotopes, however, there is a need and indeed, a demand, for information on existing applications. Radioisotopes are not being used as much as they could be. It is estimated that British industry has saved somewhere in the region of £3m. a year through their use and this figure could be greatly increased if it were not for the ignorance which exists, particularly amongst the lay public.

Many people are still, unaware of even the simplest and most straightforward uses of radioisotopes. Furthermore, there is scant knowledge as to their exact nature and how and why they are made. Rather sadly, prejudices against isotopes because of their radioactive nature still abound. There are firms, well known ones, too, which, while accepting that isotopes could be of benefit to them refrain from using them for fear of running foul of their employees and the public, despite the knowledge they are as safe to use as butchers' knives.

Then there are firms and organizations, though aware of the possibilities of isotopes, are ignorant of how they could be properly applied to their own particular problems. Further, the economics have not been suitably delved into.

Through exhibitions, films, talks and the co-operation of the press, the United Kingdom Atomic Energy Authority and other interested bodies are slowly overcoming the prejudices and fears held by the public. Sometimes, their work is harassed by the more sensational newspapers who delight in making " scare stories " out of the loss of a comparatively harmless isotope and the television programmes who thoughtlessly sanction a particularly sensational play about radioactivity.

In the industrial field the UKAEA has been making better progress. The courses arranged with the Institute of Directors with the idea of giving senior business executives a background to isotope production and application have proved highly successful and similar courses are now to be given to senior trade union officials. And the newly established Isotope Information Bureau in London, in the short time of its existence has already attracted promising support. All the same there is much ground yet to be covered and we intend that " Isotope World " will make a valuable contribution to this end.

Every month we will give details of new radioisotope developments and applications, and will draw attention to existing uses. We will also give coverage to conferences and other events at which radioisotopes is the subject. Notes and short items on firms and personalities in the field will also be included and there will be reviews of appropriate books and equipment. In short it is our aim to ensure that " Isotope World " will provide a useful service to readers and that its pages will be as thoroughly and as widely read as those of the rest of the journal.

* * *

THE establishment of a food irradiation information centre at Saclay in France is welcome. Expert opinion is sharply divided as to the suitability of and immediate need for the application of radiation as a means of food preservation. Many scientists point out that though it is technically sound there are aesthetic and economic problems to overcome before it becomes a worthwhile practical proposition. Others feel differently. They believe that such setbacks are very temporary and that there is in fact an urgent need for this new and effective means of large scale food preservation. The Centre will enable a wider hearing to be given to the whole subject and for the protagonists particularly this could mean an earlier implementation of their ideas than expected. The wastage of food throughout the world is certainly staggering. If irradiation can be used to alleviate some of the malnutrition, suffering and privation that results then it should be used. It is so very easy for us in well-fed, affluent societies to overlook the sufferings of other less fortunate people.

Behind the setting up of the Centre is the OEEC, which has already proved itself in the nuclear field as an active dynamic body. Eurochemic, Dragon and Halden are already projects to reckon with and in food irradiation matters OEEC has not been altogether dormant. A study group was set up in January to investigate and consider the various problems involved and to advise on the implementing of research programmes and the establishment of radiation facilities. Advisers from America have been over to give a helping hand and there is talk of the possibility of mobile radiation units being introduced.

THE INSTITUTION OF NUCLEAR ENGINEERS

Fleck is Chief Speaker at Dinner

Council is Enlarged

Congratulations from U.S.

Sir Alexander Fleck, KBE, DSc, LLD, former chairman of Imperial Chemical Industries Ltd., is to be the principal speaker at the inaugural dinner of the Institution of Nuclear Engineers to be held at the Savoy Hotel, London, on October 3rd at 7.0 p.m. for 7.30 p.m. Many distinguished diplomats, politicians, industrialists and scientists have been invited to attend and the dinner should prove to be a most auspicious occasion.

Council Vacancies

THE Council of the Institution of Nuclear Engineers has decided to increase its membership by five. There are thus five vacancies to fill and members of the Institution who would like to serve, or know of a member who could serve, are invited to send relevant details to the Secretary at 147, Victoria Street, Westminster, London, S.W.1.

Among the particulars required will be the amount of time the prospective member can devote to Institution activities and, if appointed whether he would be willing to serve and have the time to attend Council meetings in London. It would also be useful to state the candidate's particular interests in nuclear energy and what positions are held.

Nominations will, of course, have to be supported by a proposer and seconder, both of whom must be Institution members.

A ballot of all Institution members will be held to elect the new Council members if more than five applications are received.

Congratulations

Congratulations on the formation of the Institution of Nuclear Engineers have been received by Sir John M. Duncanson, president of the Institution from Dr. M. C. Leverett, president of the American Nuclear Society. The text of the letters exchanged between Dr. I everett and Sir John follows:

Sir John M. Duncanson,
19, Rutland Court,
Knightsbridge,
London, S.W.7, England.

SIR: It gives me great pleasure to extend the congratulations of the American Nuclear Society to the Institution of Nuclear Engineers. My colleagues and I were indeed gratified to learn of the formation of your organization and are hopeful that there will be many contacts between members of our organizations.

Through associations such as the Institution of Nuclear Engineers, the advancement of science and engineering will certainly gain impetus. I am sure your members will benefit from this association as ours have and through the cross fertilization of ideas and techniques your organization will make a sizable contribution to the technical growth of the nuclear industry.

Again, I wish to extend my congratulations and best wishes to you and the members of the Institution of Nuclear Engineers.

Sincerely yours,
M. C. LEVERETT,
President,
American Nuclear Society.

Miles C. Leverett, Esq., President,
American Nuclear Society,
86, East Randolph Street,
Chicago 1, Illinois, U.S.A.

SIR: It was with great pleasure that I received your letter of June 24th and the sentiments you express therein about our Institution of Nuclear Engineers.

We have felt, like you, that there is a place for us in this age to provide an umbrella for those connected with this new technique. That in itself calls for the development of as close a connection as possible between us.

I shall be laying your letter before the Members of Council when they meet in September but in the meantime I have had the pleasure of showing it to our Vice-President, Mr. David Watt, and to our Secretary, Mr. John Pinkerton, and both of them have asked me to couple their names with mine in thanking you and your Members for your congratulations to us.

It is our intention to publish your letter and this reply in our magazine for September, when I shall have great pleasure in sending you some copies.

We are having our first annual dinner at the Savoy Hotel on October 3rd, and should you or any of your colleagues be over here at that time, we extend a very sincere invitation for you to be our guests.

Warm regards,
Yours very sincerely,
JOHN M. DUNCANSON,
President,
Institution of Nuclear Engineers.

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Containment Vessels for Reactors BR II and BR III at Mol

by

G. Herzet, P. Laval and G. Martelée

This is the first of three articles describing the design, construction, erection and testing of the pressurized containment vessels for the BR II and BR III reactors at the Belgian Nuclear Energy Research Centre at Mol. In this article the authors, all engineers with Cockerill-Ougree, manufacturers of the vessels, discuss the problems associated with containment vessel design and give general features of the Mol reactors. The quality of steel used is also discussed

As is known, Belgium has decided to set up a huge nuclear plant, powerfully equipped with the means of study and research, where leading personnel may be trained and the technical bases established for the great atomic industry of tomorrow.

In accordance with this scheme, two nuclear reactors, designated BR II and BR III, are being built at Mol, in Campine, and are expected to come into service this year. It is important to set out very briefly the essential characteristics of these two reactors, as the particular details of their containment vessels are directly determined by them.

The BR II is a materials testing reactor of very high flux. It is not required to produce usable power, and the heat energy to which it gives rise is absorbed by a cooling arrangement. It is intended essentially for the experimental study of the materials and combinations that will be involved in the construction of future power reactors. For this purpose, it is fitted with a very compact core of highly enriched uranium, where samples are submitted to a neutron bombardment of such intensity that its results can be seen after relatively short periods of exposure. The reactor core has been designed by the American firm NDA (Nuclear Development of America), so as to afford wide possibilities of adaptation and very great flexibility in use. Numerous channels have been provided for the introduction of samples in accordance with a very carefully designed scheme that affords exceptional facilities for carrying out experiments.

The BR III is a PWR type (pressurized-water power reactor) comparable to those in the American plant at Shippingport and the atomic submarines; the specifically nuclear part has been supplied by Westinghouse. Its very low power output—11,500 kW—clearly takes it out of the range of economic viability; it is essentially a place for training specialists. It may be recalled that the initial intention was to build it at the Heysel, for the Universal and International Exhibition, Brussels, 1958, but various considerations caused this plan to be abandoned at the last moment.

The consequences of fall-out in the atmosphere of radio-active products due to an accident to a nuclear reactor may be grave. Hence all steps must be taken, regardless of cost, to avoid the occurrence of such an eventuality.

In spite of so many precautions, it has always hitherto been considered wise to enclose within a huge perfectly airtight steel pressure vessel all the specifically nuclear parts of the reactor and any circuits liable to become activated when in service.

World Wide Examples

At the present time, nearly 30 vessels of this type have been built or are in the process of being built throughout the world. We may cite, as particularly spectacular examples, the sphere over 223 ft (68 m) in diameter, built at West Milton (U.S.A.) for testing the sodium-cooled SIR-A reactor; the 190 ft (58 m) one built at Dresden for the General Electric boiling water reactor; the 180 ft (55 m) one being built at Chinon (France) for the EDF 1, and the 134 ft (41 m) one built at Dounreay (Scotland) for the British fast-breeder recently brought into service.

There are others of all types and sizes; it will be seen that the containment vessels of the BR II and BR III, the subjects of the present article, occupy a very interesting place amongst them.

Purpose of Vessel

The purpose of the steel pressurized containment vessels is thus to ensure the almost complete airtightness of their interiors vis-à-vis the atmosphere, so as to prevent the dispersion of radioactive products that might fall out in the case of an accident. Under test pressure, the tolerated rate of escape is extraordinarily low, of the order of several tenths of one per cent. over 24 hr, and conformity to this regulation is checked by a series of extremely severe trials, which will be later described.

This airtightness demands first of all absolutely impeccable execution of welded joints. This is one of the reasons in the BR II and BR III why controlled welding has been wherever possible by radiography and ultrasonic testing, and, during a pressure test to be described further on, we checked their absolute airtightness by the soapy-water method.

Next, the airtightness of the pressure vessels must be maintained, despite the often numerous openings

Fig. 1—Overall view of the BR II reactor

Fig. 2—The BR III containment vessel

which must be provided to permit the ingress and egress of personnel and gear, the extraction of spent fuel units, which are intensely radioactive, the passage of pipelines and cable runs and the introduction of samples, etc. These provide a series of special problems; for example, airlock chambers with airtight double doors, suited to prevent their being opened simultaneously, have to be provided for the entry of personnel and even of vehicles.

Danger Points

The possibility of significant quantities of energy escaping exists under certain circumstances. Thus, in reactors cooled or controlled by water, energy contained in the fluid at high pressure and high temperature may be suddenly liberated by a tank or a pipe bursting. Steam is then diffused throughout the interior and rapidly raises the pressure and temperature there. The most critical state reached in this way may be calculated to a sufficient degree of approximation from simple thermodynamic considerations if the circuit characteristics are known on the one hand, and the volume of the interior on the other, where the escaped steam can diffuse. It is physically evident that the pressure reached is the lower as the volume is greater, so that there is an optimum size for the pressure vessel. The latter, moreover, may or may not be compatible with the size requirements of the equipment and the biological protection shields (shields of concrete and other materials which absorb radiation).

When accidents occur, the pressure inside the vessel may increase under the effect of chemical reactions, *e.g.*, that of water with the zirconium which in certain cases forms the coating of the fuel elements, or the combustion of the sodium used in cooling certain reactors. In point of fact, these phenomena are imperfectly understood and continue to be the subjects of research in specialist laboratories. It will be observed that they are not specifically nuclear in any way, but may be occasioned by some disorder in the nuclear system and by the local overheating which results.

Taken all in all, the evaluation of the ultimate pressure capable of developing inside, and for which the vessel must be calculated, still involves a number of uncertain elements. To give some practical notion, we may say that the pressures allowed for in the principal steel vessels already built or in course of construction range from 14.2 to 64 lb/sq.in. (1.0 to 4.5 kg/sq.cm).

The containment vessel must also resist, without caving in, the deepest depressions that can occur within its interior.

Finally, the building must resist wind and snow, and combine the contingency of their effects with those of an accident.

In conclusion it is pointed out that the containment vessels are only submitted to stresses in very exceptional circumstances. These, however, must be allowed for and the quality of design and execution must be of a high order.

Concrete a Possibility

There exists—or could be designed—a large variety of types of airtight containment vessels.

First of all the type of material must be considered.

At the present time, all these structures are in welded steel. The use might be envisaged of prestressed concrete, which has already been employed in France for the

pressure tanks of the gas-cooled reactors G_1 and G_2 at Marcoule. Nevertheless, we believe that for a long time to come this material will only be found suitable for small-scale structures, and it may be doubtful whether it is capable of providing the requisite airtightness.

It might be asked whether it would not be better to bury the whole installation underground, simply covered by a light metal cladding resting on the soil. Detailed investigation shows, however, that owing to the possibility of earth movements, this solution is often more costly and less certain that constructing a steel containment vessel.

Part Subterranean

Compromise solutions may be imagined, however, and the base of the building could be buried in the ground at a greater or lesser depth. This is what is most frequently done, to ensure that the building has good stability. How deep the structure is buried varies greatly, according to the nature of the terrain, the character of the water table, the general design, means of access, etc.

Next, possible shapes must be considered.

In principle, a spherical shape is the most recommended, because it presents the smallest surface for any given volume, and the most favourable and uniform distribution of stresses. This shape has in fact been used for a number of the largest pressure vessels.

It must, however, be observed that horizontal sections across the sphere vary rapidly as a function of their level, and for certain types of reactor and for certain installation layouts this may occasion a very poor use of the space available. Furthermore, as may be imagined, the erection of a large-size sphere involves serious difficulties.

Hence in a considerable number of cases, a cylindrical shape has been retained.

Choice of Base

The problem arises next of what shape to give the base; this may be hemispherical, ellipsoidal, a three-centred curve or flat. A hemispherical shape clearly offers the advantages mentioned above for the spherical shape, but it also has a number of drawbacks. It corresponds to the greatest depth of any given diameter, and hence, where the base of a partly buried container is involved, major works of excavation and infilling are required. Where a dome is concerned, and the biological shielding is omitted for reasons of economy or ease of construction, it gives rise to a higher degree of radiation towards the vicinity than any other. This is why attention has been directed towards ellipsoidal and three-centred curve bases.

Another fundamental design choice is the following:—shall the pressure vessel consist of a simple steel wall sufficiently resistant in itself, or shall it be constructed with ribs and stiffeners? Examples exist of both solutions. The first, however, is by far the most frequently selected, as the second has the drawback of involving a mass of complicated contingent calculations, since the ribs occasion secondary bending stresses that are sometimes of major importance.

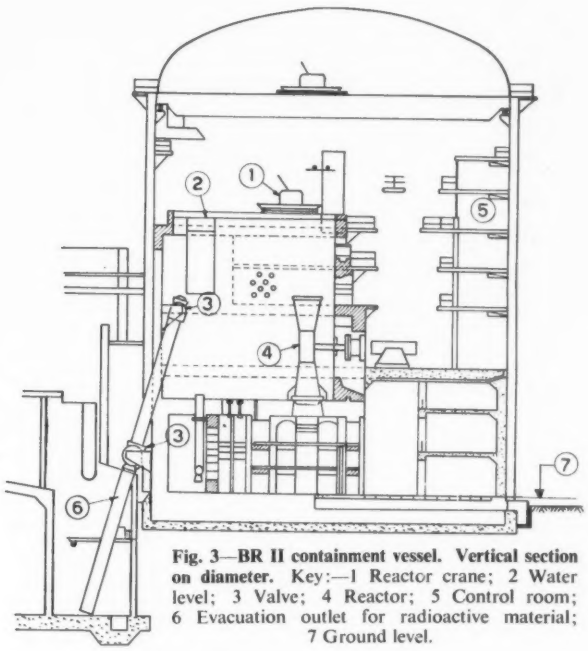


Fig. 3—BR II containment vessel. Vertical section on diameter. Key:—1 Reactor crane; 2 Water level; 3 Valve; 4 Reactor; 5 Control room; 6 Evacuation outlet for radioactive material; 7 Ground level.

The first kind, which presents a continuous variation of curvature and hence fewer secondary bending stresses, is theoretically preferable, but the second, which only has two radii of curvature, is easier to construct in metal, and thus has an undeniable practical attraction. As regards a flat base, its resistance proper is obviously nil for reasonable thicknesses, and it could only be used if sunk in a very thick concrete slab, when the latter is required for the foundations and biological protection. This solution is, moreover, restricted to low pressures, because it sets the problem of effectively transmitting stresses from the cylindrical wall to the base. Its interest lies in the fact that it requires little in the way of excavation.

All airtight pressure vessels are equipped inside with a polar travelling crane, which is needed for servicing the equipment. The runway for this may be solid with the vessel, which then becomes subjected to complex stresses and must be suitably stiffened, which, as we have seen, is undesirable. It can rest on independent steel stanchions; and finally, it can rest on an internal cylindrical reinforced concrete wall forming a protective shield on the periphery of the building.

Fig. 3 shows a vertical diametrical cross-section through the BR II containment vessel.

Although some of the basic lines were determined by the firm of NDA who designed the reactor, the planning of this airtight pressure vessel

was carried out completely by the Société Cockerill-Ougrée, in close collaboration with the technical services of the BEN and Sofina, acting in the capacity of consultant engineers to the CEN, the building owners. Site control and supervision were carried out by the Association Vinçotte.

Flat Base: Dome Top

In shape, the pressure vessel has a cylindrical body with a flat base and a torispherical dome (a three-centred curve). The flat base was adopted with a view to reducing the need for excavations to the minimum, which was particularly desirable on account of the height of the water table at Mol.

The cylinder has a diameter of 104 ft, its height is 121 ft and it is embedded in the ground to a depth of 17 ft. It is built up of 14 rings, each of which in its turn consists of 16 sections, which thus have a height (except for the top ring) of 8 ft 11 in. and a developed length of about 20 ft 5 in. The thickness of the plate is 0.7 in. except for the two bottom rings, where it is 1 in. The latter thickness was adopted to avoid, at the point where the cylinder meets the dome, the effects of the change of curve coming on top of those due to the change of thickness. The welds between plates, involving complete penetration, are of the asymmetrical double-bevel butt-weld type for the vertical joints, and of single-bevel butt-weld type for the horizontal joints (Fig. 4).

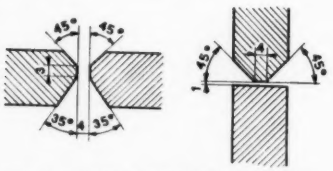


Fig. 4—Welds of the double-bevel, butt type (*left*) and single-bevel butt type (*right*)

The flat base is carried out in plates 0.3 in. thick, welded together with V beads on supporting flats and by double angle beads at the base of the cylindrical body. It is obvious that this base resists no stresses and does not have to be calculated; it simply constitutes an airtight position between the foundation raft on which it has been placed, and the inner slab of reinforced concrete, some 16 ft 5 in. thick, which surmounts it.

Fig. 5—Laying flats in the base slab

The problem then arises of how to transmit, under the best conditions, the vertical thrust exerted on the dome. This thrust, which at the pressure calculated reaches a value of over 7,000 metric tons, is sustained by the cylinder when the pressure rises inside. To meet these conditions, the two lower rings of the cylindrical body, which are concreted and hence reinforced, have been fitted with about 1,000 anchorage plates, inclined at 45°, 0.6 in. × 2.7 in. in section and 5 ft long, which transmit the above-mentioned thrust at a tensile load on the steel of 6.2 tons/sq.in. and a steel-concrete adherence of 56.9 lb/sq.in. These anchorage plates can be seen in Fig. 5.

Concrete Lining

A reinforced concrete wall, some 2 ft thick, runs round the interior of the cylindrical body; a 1 in. layer of very pliable insulating material separates it from the steel wall.

The dome accordingly has no internal or external cladding forming a protective shield. For this reason it has been sought to make it as flat as possible, so as to diminish the radiating surface. It thus assumes a torispherical shape, with a major radius of 72 ft 2 in. a minor radius of 8 ft 4 in. and an abscis of 25 ft 8 in. Its summit is thus some 146 ft 8 in. above the base of the building and 129 ft 7 in. above ground level. The dome is 1 ft thick; it is made up of six concentric petals and a central cap in two pieces. All the welds are of the asymmetrical double-bevel butt type with a 60° throat, the large double bevel showing outwards, so as to reduce to a minimum the amount of welding to be carried out on the soffit.

A circular gallery 2 ft 3 in. wide with a handrail and an access stair running up from ground level provides facilities for the inspection and upkeep of the dome.

The gross volume of the interior of the BR II is about 1,200,000 cu.ft.

The special character of reactor BR II, which is essentially experimental, makes the provision of a particularly large number of openings in the pressure vessel necessary.

Fuel Sheath Problems

Most of the openings have been devised in such a way that it is possible, in the course of service, to submit them to an air pressure test to check their airtightness separately and independently of the pressure vessel. For this purpose, the two ends can be sealed by airtight covers.

The different air-locks will be described later. At this point, a word will be said about the two sheaths for the passage of fuel and samples. Their slight inclination (20°) in relation to the wall of the cylindrical body creates at their intersection with the latter a very elongated ellipse that constitutes an incision which greatly weakens resistance. It also creates design difficulties in placing welds and securing access to them for execution and control. The shape of these openings, and the reinforcements they require have thus necessitated the greatest care in design. The reinforcement was carried out in two parts of different thicknesses, one 2.75 in. strip surrounding the sheath directly, and a 2 in. strip going over

this. Fig. 6 shows one of these sheaths, with its reinforcement, which was constructed in the workshop.

It may be noted in conclusion that the weight of steel in this container with its air locks and different openings, is about 1,000 metric tons.

The design for the containment vessel for BR III was commissioned from the American firm of Sargent & Lundy. They worked in collaboration with Westinghouse, who were responsible for the general design of the whole scheme and for the supply of the main nuclear parts of the installation. Cockerill-Ougrée were the main contractors. BEN and Société de Traction et d' Electricité acted as consultant engineers to CEN, the building owners. Site control and supervision were carried out by the Association Vinçotte.

Unribbed Type

This building is cylindrical in shape; its dome is spherical and its base torispherical. It is of the unribbed wall variety. The polar travelling crane does not stress the vessel, its reactions being taken up by the massed concrete walls inside. An internal concrete shield protects the whole of the dome, so that the spherical shape could be adopted for it without any difficulties; the torispherical shape of the base was chosen to reduce the amount of excavation required.

During erection, the pressure vessel rested on 12 stanchions, cross-braced between each other, two by two. These stanchions were calculated to sustain, not only the self-weight of the structure, but also the stresses due to a gale-force wind and even to seismic movements of moderate intensity which may occur in our regions.

In its final state, the building will be embedded in the ground to a depth of about 25 ft 7 in., the erection columns will be cut away; the base, between major masses of internal and external concrete will only serve to ensure airtightness, and the while structure will possess a very stable seating.

The cylinder has an internal diameter of 54 ft 3 in. its height is 66 ft 2 in. It is made up of eight rings, each of which consists of eight sections which thus vary in height from 7 ft 10 in. to 8 ft 10 in. approxmately, with a developed length of 21 ft 3 in. The plate thickness is uniformly $1\frac{1}{8}$ in.

The base is also carried out in $1\frac{1}{8}$ in. plate. It is a three-centred curve, with a major radius of 49 ft 1 in. a minor radius of 9 ft 4 in. and an absciss of 13 ft 7 in.

Novel Idea Abandoned

The hemispherical dome presents a peculiar feature in that it was designed and calculated to accommodate in its upper part a huge reservoir, of lenticular shape, intended to contain a solution of boron salt which could have been released into the interior in case of accident to absorb the neutrons that would be freed. After discussion, this reservoir was abandoned, but the initial design of the dome was retained, and it thus features three concentric zones of different thicknesses, a lower zone $^{13}/_{16}$ in. thick, a middle zone of $^{9}/_{16}$ in. and an upper one forming a cap $^{11}/_{16}$ in. thick.

A fixed gallery 2 ft 3 in. wide, with a guard rail, runs round the cylinder for half its circumference near the springing of the dome, and joins the roof of a neighbouring building. A large ladder turning through the arc of a circle gives easy access to the dome for inspection and maintenance; the centre pivot is mounted on rollers, and the ladder bears on a lower circular track via adjustable runners mounted, in their turn, on rollers.

The gross volume of the interior of the BR III is about 230,000 cu.ft (6,500 cu.m).

We may note in conclusion that the weight of steel of this pressure vessel with its air locks, its fuel transfer tank and its accessories is about 430 metric tons.

The choice of steel used for these structures does not involve any specifically, nuclear considerations. These structures are not, in fact, normally subjected to any great degree of radiation; in particular no limit of cobalt content is imposed.

The questions at stake are essentially those of weldability, a carbon steel with averagely high mechanical properties being sufficient.

Certain mild steels which prove perfectly ductile under conditions of traditional tensile test are susceptible, in certain unfavourable circumstances, of behaving as if fragile, *i.e.*, they break without notable

Fig. 6—One of the factory built sheaths, with its reinforcement

prior elongation and with a tendency to propagate started cracks rapidly.

Among the factors that promote this fragile behaviour, are high nitrogen, oxygen, hydrogen, phosphorous and sulphur contents and a coarse metallographical structure in the steel, the polyaxial character of the stresses; the sudden application of stresses due to shock; and the existence in the structural steel of a high elastic potential capable of being set free when fissures are caused, low temperatures also contribute to this fragile behaviour.

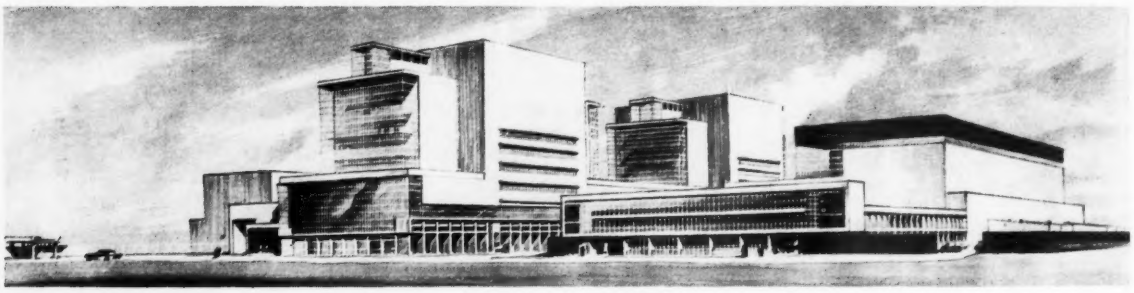
All these factors, generally speaking, are of the kind that facilitate fracture by wrenching, by detaching the crystalline planes from each other under the effect of normal stresses, instead and in place of the shear fracture of the crystalline planes over each other through the effect of tangential stresses.

Steel Must be Right

In the particular case of the steel pressure vessels under consideration here, if certain conditions are favourable from the point of brittle fractures—such as the moderate thicknesses of the plates employed, except for certain reinforcements where they reach 2 in., 2.75 in. and even 6 in. and a certain deformability of construction by reason of their thin wall structure—other conditions are less favourable in this respect. In the event of an accident, stresses can be applied in a fairly abrupt manner. While in service, the temperature of the metal may descend to a low level possibly to −4°F. At the intersection of vertical and horizontal welds, or in the proximity of reinforcements

(*Continued on page 420*)

Work has started on the 550 MW N-Station at Dungeness



An artist's impression of station when completed

BRITAIN'S sixth commercial nuclear power station, to be sited at Dungeness, on the English South Coast, will have a net electrical output of 550 MW. Generating heat will be provided by two carbon dioxide cooled, graphite-moderated reactors each with a heat output of 840 MW.

The station will be built for the Central Electricity Generating Board by the Nuclear Power Group, the partnership formed at the beginning of this year by The Nuclear Power Plant Co., Ltd., and AEI-John Thompson Nuclear Energy Co., Ltd. Work on site has started and the station is scheduled to be completed and handed over to the CEGB in 1965.

Little Disturbance

The site of the station is on the western side of the Dungeness point and is close to deep water in the English Channel. As the area is of considerable interest to naturalists and physiographists, special arrangements have been made by the Generating Board to minimize any disturbance to the natural life and surface features of the area during the constructional period and during the operation of the power station.

The land which has been purchased by the Generating Board is of shingle and has no agricultural value whatsoever. It is on level terrain. Circulating water will be taken from, and returned to, the English Channel at a rate of about 21¼ m. gal/hr.

Each reactor will have a prism-shaped, graphite core, made up of large octagonal and small square

(*Continued on page 409*)

Some Facts and Figures

Performance	
Net electrical output	550 MW
Heat output per reactor	835 MW
Efficiency	32.9 per cent.
Reactor gas bulk outlet temperature	410°C.
Reactor gas inlet temperature	250°C.
Nominal max. can surface temperature	442°C.
Nominal max uranium temperature	563°C.
HP steam pressure at blower TSV	1,410 lb/sq.in. abs.
HP steam temperature at blower TSV	392°C.
LP steam pressure at main TSV	550 lb/sq.in. abs.
LP steam temperature at main TSV	391°C.
Feedwater temperature	180°C.
Fuel	
Number of fuel channels per reactor	3,876
Number of elements per channel	7
Overall length of fuel element	41.7 in.
Dimensions of uranium rod	37.6 in. × 1.10 in. diameter
Total weight of uranium per reactor	298 tonnes
Core Dimensions	
Diameter of active core	45 ft 4½ in.
Height of active core	24 ft
Diameter of reflector	50 ft
Height of reflector	27 ft 10 in.
Lattice (square) pitch	7.75 in.
Gas Circuit	
Mean diameter of reactor vessel	62 ft 6 in.
Reactor vessel general thickness	4 in.
Gas working pressure	283 lb/sq.in. abs.
Number of gas circuits per reactor	4
Diameter of gas ducts	6 ft 6 in.
Power input per blower	7 MW
Overall height of boilers	75 ft
Internal diameter of boilers	23 ft 6 in.
Shell thickness (graded)	3⅜ in. to 2⅜ in.
Turbo-Alternators	
Number of main turbo-alternators	4
Continuous maximum rating/set	142.5 MW
Speed	1,500 rev/min
Generator voltage	13.8 kV
Vacuum	28.9 in. Hg
Exhaust wetness	14.3 per cent.
Total circulating water quantity	353,000 gal/min
Layout	
Distance between reactor building centres	426 ft
Length of reactor building	316 ft
Length of turbine house, only	385 ft

bricks, enclosed in a spherical steel pressure vessel. The vessel will be surrounded by a primary biological shield of concrete through which pass the gas ducts to four boilers. Dry carbon dioxide at a pressure of 283 lb/sq.in. abs. will be circulated between the reactor core and the boilers by four blowers driven by back pressure steam turbines. Each reactor unit will have its own control system, fuel store, on-load fuelling equipment and fuel cooling pond.

The turbine house will contain four 142.5 turbo-alternators. The steam and electrical connections between reactor units and turbine house will be taken underground through tunnels. The steam will be generated in the boilers at two pressures, 1,418 lb/sq.in. abs and 590 lb/sq.in. abs. All the higher pressure steam will be passed through the back pressure turbines driving the blowers. These turbines will exhaust at the LP pressure and after reheating in the boilers, this steam will be passed with the LP steam to supply the main turbines. The overall station efficiency when working at these conditions will be 32.9 per cent.

The station will be connected to the national grid (275 kV for connection to supergrid) in the same way as any conventional station.

A Goliath crane of 400 tons lifting capacity, will be used to transfer both light and heavy parts of the reactor plant from the construction or delivery areas into the reactor areas. Heavy parts to be lifted include boilers, pressure vessel segments, etc.

To Use Local Labour

The station working area will be 112 acres, and when complete the station will occupy 40 acres. It is anticipated that the peak labour force employed during construction will be approximately 1,800. A large proportion of the labour will be drawn from local towns and villages.

The CEGB made application to the Minister of Power for consent to build Dungeness nuclear power station in June, 1958, and a public inquiry was held at Lydd, in December, 1958. The Minister of Power gave his consent for the construction in July, 1959.

Four nuclear power stations are now under construction for the CEGB, at Berkeley, Gloucestershire (275 MW), Bradwell, Essex (300 MW), Hinkley Point, Somerset (500 MW) and Trawsfynydd, Merionethshire (500 MW). The Minister of Power has given his consent for another station at Sizewell in Suffolk, and his decision is awaited for a further site at Oldbury-on-Severn.

The South of Scotland Electricity Board has one nuclear power station under construction, at Hunterston, Ayrshire (300 MW).

The Nuclear Power Group, who are to build the station comprise Associated Electrical Industries Ltd., Clarke, Chapman & Co., Ltd., Alex. Findlay & Co., Ltd., Head Wrightson & Co., Ltd., Sir Robert McAlpine & Sons Ltd., C. A. Parsons & Co., Ltd., A. Reyrolle & Co., Ltd., Strachan & Henshaw Ltd., John Thompson Ltd., and Whessoe Ltd.

I.A.E.A. to Assist Eleven Countries

ASSISTANCE to the peaceful development and application of nuclear energy in 11 countries, in the form of services of experts and equipment, valued at a total of U.S. $320,000, was recently approved by the board of governors of the International Atomic Energy Agency. Earlier in the year they approved similar assistance to the value of $279,190. The funds are allocated in response to requests for technical assistance to specific atomic energy projects in the Agency's member states. Of the amount recently allocated, $120,000 represents resources available from the Agency's own operational fund, while $200,000 represents a special contribution by the United States for the provision of equipment for approved technical assistance projects. Out of the total amount, $63,800 will be spent on securing the services of six experts, and $256,200 are to be spent on equipment and supplies. The countries which will receive this assistance are Afghanistan, Argentina, Brazil, Greece, Iceland, Israel, the Philippines, the Sudan, Turkey, the United Arab Republic and Venezuela.

Afghanistan is due to receive equipment worth $23,000 for a nuclear physics laboratory at the University of Kabul. Equipment valued at $23,000 will also be provided to Argentina to supplement the work of an expert made available to that country under the U.N. Expanded Programme of Technical Assistance. In March-April this year, the board of governors approved the sending of a nuclear metallurgy expert to Brazil to assist in setting up a metallurgy laboratory at the Institute of Atomic Energy at Sao Paulo. It has now been decided to supplement the work of this expert and the Agency will provide equipment at an estimated cost of $30,700. Greece will receive a Van der Graaf accelerator, together with the necessary accessories, valued at a total of $32,000, for a nuclear physics laboratory.

The services of an expert will be made available to assist the physics laboratory of the University of Iceland in the uses of isotopes in hydrological studies for the development of energy resources. To help the expert in his work, the Agency will also provide measuring and analytical equipment. The total value of the assistance is estimated at $33,700. The Government of Israel intends to hold a course in radiobiology and the medical applications of radioisotopes, from March to July, 1961, at the Radioisotope Training Centre set up by the Weizmann Institute of Science. To assist this project, the Agency will provide a visiting professor in radiobiology and some equipment, at a total estimated cost of $16,000.

The Atomic Energy Commission of the Philippines is conducting a course in radioisotope techniques, for which the Agency has already provided a radiochemist and some equipment. It will now provide equipment to the value of $16,000.

A health physicist is scheduled to visit Turkey to advise the authorities on the establishment of a central health physics laboratory, to deliver lectures at the universities of Ankara and Istanbul, and to advise the Turkish Atomic Energy Commission on activities to promote the health physics programme. Another expert in the medical applications of radioisotopes will be provided for the Medical Faculties of Ankara and Istanbul universities and the hospital in Ankara, where he will give lectures and train personnel in the diagnostic and therapeutic applications of radioisotopes. For the work of this expert, the Agency will provide some equipment. It will also supply equipment for the universities of Ankara and Istanbul and some associated equipment for a sub-critical assembly. The total value of the assistance provided to Turkey is estimated at $66,100. One expert in the field of radioactive raw materials will be sent to the United Arab Republic to assist in the planning and implementation of a programme for the exploration and evaluation of radioactive deposits in the country. Some equipment will also be provided in this connection. The total cost of the assistance will be approximately $17,700. Both the United Arab Republic and the Sudan have requested the Agency's assistance in measuring environmental radioactivity, in response to which an expert and some equipment will be provided. In the Sudan, the expert will supervise the setting up of the equipment and train personnel in its operation and maintenance. He will also advise the authorities in the U.A.R. on establishing monitoring stations. The total cost is estimated at $14,400. One expert in the production, handling and use of radioisotopes and a variety of equipment, to the total value of $47,400, will be provided to Venezuela to assist in organizing training courses and in the planning of a research programme.

Greater safety for hands

With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

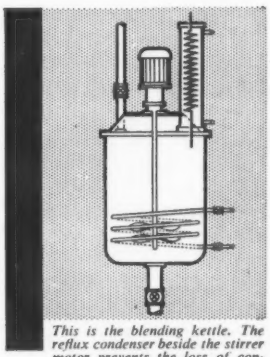
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organization have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication

No Reductions yet in EXPENSIVE NUCLEAR RESEARCH

according to Sir Christopher Hinton

RESEARCH and development costs in the nuclear power plant field are about 30 per cent. of capital expenditure, according to Sir Christopher Hinton, KBE, FRS, chairman of the Central Electricity Generating Board, and are likely to remain at this figure. In the conventional field, however, research and development costs represent no more than 5 per cent. of the capital value of power plants built. And, estimates Sir Christopher, power from nuclear plants now being ordered would cost 25 per cent. more than from conventional plants built concurrently and operated under similar load conditions. Furthermore, the advanced gas cooled reactor system, a prototype plant of which is now being built at Windscale, would show little, if any, immediate advantage over the improved Calder Hall reactor system.

These points were made by Sir Christopher in the paper, " The Evolution of Nuclear Power Plant Design " he delivered at the Tercentenary Celebrations of the Royal Society in London during July. The paper outlined the technological problems involved in the development of the gas cooled type of reactor and related them to power costs. Though drawing attention to the high costs involved in nuclear research and development and showing how they appear immediately to bear little relation to the value of the end product Sir Christopher said he felt that they would ultimately be justified. Nevertheless, he could not resist adding that it would be interesting to speculate how much the downward trend in the cost of conventional power could be increased if it had attracted as great a research and development effort as its nuclear rival.

Sir Christopher started his paper by saying that applied research and development on atomic energy was so expensive that expenditure should be justified either by the needs of defence or by the expectation of a satisfactory return in the industrial field. " The foundations of the atomic energy industry," he said, " were paid for with defence funds." This applied even to the Calder Hall reactors which were built primarily for plutonium production and generated electric power as a by-product. However, little of the research and development undertaken in the industrial field could now be charged to a defence budget.

Changes Since 1955

Three important changes had taken place since the British nuclear programme was launched in 1955. The cost of conventional power had fallen by more than 10 per cent; the credit for plutonium (a by-product of commercial reactors) had been drastically reduced, and interest rates had risen. As a result of these changes, nuclear power from the plants now being ordered would cost about 25 per cent. more than from the best conventional plants built concurrently and operated under similar load conditions.

Uneconomical but Justified

The plans of nuclear power had also been affected by the change in short and long term forecasts of coal supplies, and the programme was last revised in June, 1960. Nevertheless, a programme involving the construction of many successive nuclear power stations, each of which would be less economical than conventional stations, was still justified in view of the promise that nuclear reactors would give cheaper power than could be obtained from conventional fuels at a reasonable date in the future.

Nuclear power would be made cheaper by using higher temperatures in the heat cycle. But advances in technology, bringing down the cost of power were still taking place in the conventional field.

Turning to capital costs of conventional plant, Sir Christopher pointed out that from the earliest days of the steam engine there had been a continuous fall in the cost per unit of output. Looking to the future, other factors had to be taken into account such as the transport of large generating units to site and the stiffness of interconnection of the electricity Grid system. It was also necessary to forecast the cost of fuel, and this was far more uncertain than forecasting capital cost and thermal efficiencies, either in the conventional or the nuclear power plant fields.

Temperature Problem

If, with atomic power, we could achieve the same top temperatures in the heat cycle that were used in conventional power stations, nuclear power could today be cheaper than conventional power. The lower temperature of nuclear plants was entirely due to problems within the reactor. Primary problems involved the material used for canning the fuel elements, the fuel itself, and the behaviour of the graphite moderator under heat and irradiation.

Secondary problems were those of reactor stability and control which became more acute when higher ratings and burn-ups were used. With the low burn-ups used at Windscale, the reactors had a negative temperature coefficient and were self-regulating. At higher burn-ups the build-up of plutonium reversed that part of the temperature coefficient which was associated with the graphite. The overall effect was that control should be by movement of the control rods, and care should be taken to see that departure from normality could not be too rapid to be corrected with absolute certainty.

Poisoning More Acute

Xenon poisoning also became more acute at higher ratings and could make it difficult to restart the reactor after a shut-down. It was fortunate that the fuel element

temperature coefficient remained negative and was strong enough to give an effective stabilizing influence on rapid transients.

Sir Christopher also dealt with problems of engineering construction which were mainly connected with the pressure system. These problems —of fabrication, brittle fracture, welding and design—were reduced by the use of higher fuel element ratings because the dimensions of the pressure vessel for a given heat output were reduced.

AGR Capital Costs

The advanced graphite reactor was designed to achieve a bulk gas outlet temperature of 510°C. although the gas flow was so arranged that the pressure shell was exposed only to gas at 320°C. which had passed through the heat exchangers. Either beryllium or stainless steel could be used for canning the uranium oxide fuel. Capital cost of the first industrial reactors of the AGR type were estimated at between £95 and £80/kW (sent out) and they would generate power at a cost of between 0.55*d.* and 0.50*d.*/unit or perhaps a little less at a load factor of 75 per cent.

The downward trend in cost of the nuclear power plants being built by the CEGB could be closely estimated and is shown below.

Station	Capacity (MW s.o.)	Cost (£/kW s.o.)
Berkeley	275	160
Bradwell	300	159
Hinkley Point	500	133
Trawsfynydd	500	123
Dungeness	550	110

From the general picture, three distinct lines of advance could be seen. These were firstly an increase of pressure in the gas circuit, secondly improved utilization of pressure vessel volume, and thirdly increase in fuel element and coolant temperature.

"Disquieting" Comparison

It was probable that there would be a period during which the two types of reactors, AGR and Calder, would overlap, and orders for AGR stations would be interspersed between orders for Calder type stations until ultimately the more technically advanced AGR showed a clear operating cost advantage over the older type.

"It is disquieting, however, to compare the research and development effort which is devoted to bringing down costs in the two fields" (of conventional and nuclear power), continued Sir Christopher. In analysing these costs, he stated that in the conventional field, research and development costs were of the order of 5 per cent. of the capital value of power plants built. Information was not available to determine the corresponding figure in the nuclear field, but assuming that the cost of the nuclear station of the power plants to be built for the Central Electricity Generating Board in the years 1965-1975 was rather less than £50m./year, it seemed improbable that research and development costs, if effort were maintained at its present level, would be likely to be less than 30 per cent.

Under 10 AGR Stations

It was probable that by the time the AGR went into use, research and development expenditure on the development of the Windscale prototype would have been of the order of £30m. Yet it was possible that the number of power stations built by the Generating Board using this type of reactor would be less than ten.

By the mid-1970s, advances to higher temperatures and higher ratings were likely to make the introduction of another thermal reactor necessary. The High Temperature Gas-Cooled Reactor was an effort to meet the problem by using the graphite as a canning material for the fuel and thus replacing it as the fuel elements were changed. Using enriched uranium in ceramic form in a semi-homogeneous system, this reactor, should, if successful, make it possible to achieve a temperature of over 1,000°C. in the heat cycle.

If such a system using a replaceable graphite moderator could not be evolved, the alternative would be to use heavy water as a moderator so that radiation damage could be repaired or removed during circulation. It would then probably be convenient to use steam instead of CO_2 as a coolant.

Reverting to research costs, in the nuclear field, Sir Christopher asked how long could the electricity industry justify costs of about 30 per cent. of capital expenditure.

"Remembering that the demand for electricity has a doubling period of ten years, that the total fuel requirements of the Generating Board (expressed as coal equivalent) are now 54m. ton/year and will rise to 90m. ton/year by 1970, and remembering that it is improbable that sufficient British mined coal would be available to meet the Board's total fuel requirements by some date in the 1970s, it appears reasonable to aim at continuing the high rate of advance of nuclear technology to the point where nuclear power breaks even in cost with conventional power; we shall then have room to manoeuvre in a three fuel economy. After that date, which is not remote, it is surely reasonable to think that research on reactor technology should be justified by savings which can be expected to arise from its industrial application."

Sir Christopher concluded by referring to the effect of the injection of defence technology into industrial practice. "One wonders," he said, "whether the injection of these developments into the industrial field has not over-stimulated some industries in a way which makes it hard to live with them while diverting effort from others."

MONOGRAPHS RECEIVED

An Experimental Radon-in-Air Monitor, by W. G. Sparke and J. A. B. Gibson. Published by AERE, Harwell. Ref. AERE—M 660. Available at Harwell Library.

An Apparatus for Sampling the Stratosphere, by P. Goldsmith and A. G. Parham. Published by AERE, Harwell, Ref. AERE R 3272. Available from H.M. Stationery Office. Price 2*s.* 6*d.*

A Sensitive Direct-Reading Pocket-Size Gamma Dosimeter, by J. H. Howes. Published by AERE, Harwell. Ref. AERE—R 3115. Available from H.M. Stationery Office. Price 3*s.* 0*d.*

Neutron Activation Analysis of Blood, by W. P. Hutchinson. Published by AERE, Harwell. Ref. AERE—MED/R 2317. Available from H.M. Stationery Office. Price 1*s.* 9*d.*

Resonance Integral Calculations for High Temperature Reactors, by J. P. H. Blake. Published by AEE, Winfrith. Ref. AEEW—R 25. Available from H.M. Stationery Office. Price 5*s.* 6*d.*

Errors Due to the Cylindrical Cell Approximation in Lattice Calculations, by D. A. Newmarch. Published by AEE, Winfrith. Ref. AEEW—R 34. Available from H.M. Stationery Office. Price 3*s.* 0*d.*

The Induced Charge Method of Reading Condenser Dosimeters, by E. H. Cooke-Yarnborough. Published by AERE, Harwell. Ref. AERE—M 677. Available from H.M. Stationery Office. Price 1*s.* 9*d.*

FUEL REPROCESSING

EUROCHEMIC'S PLANT AT MOL, BELGIUM

MOL, Belgium, has much to offer in its favour as the site of the EUROCHEMIC fuel reprocessing plant, work on which has just started. It is, for instance, the established home of nuclear research in Belgium and as such provides an environment most suited to the project. Furthermore, it is, in relation to the countries which will be using the plant when in operation, central.

Thirteen countries have shares in EUROCHEMIC and each one will be able to send irradiated fuel elements to Mol for processing. Accordingly the plant will be designed to cope with elements of various designs. Capacity of the plant will depend upon the type of element—for aluminium and magnesium clad natural uranium elements it will be 770 lb a day, for zircalloy and stainless steel clad elements of the PWR type it will be 440 lb a day.

In addition to the actual processing plant there will be a laboratory for carrying out research and development work in relation to the techniques employed in the main plant. This laboratory will probably be ready before the plant, but not in time for carrying out work that would be applicable to the first plant installation.

Date scheduled for start of plant tests is some time in 1963, while it is hoped to start operation proper the following year.

Industrial firms from different countries will be responsible for detailed design and manufacture of the instruments and equipment to be used in the plant, as well as for the erection of plant buildings. The Belgian authorities and the Centre d'Etudes Nucléaires will deal with the problems of waste disposal and with health and safety arrangements generally.

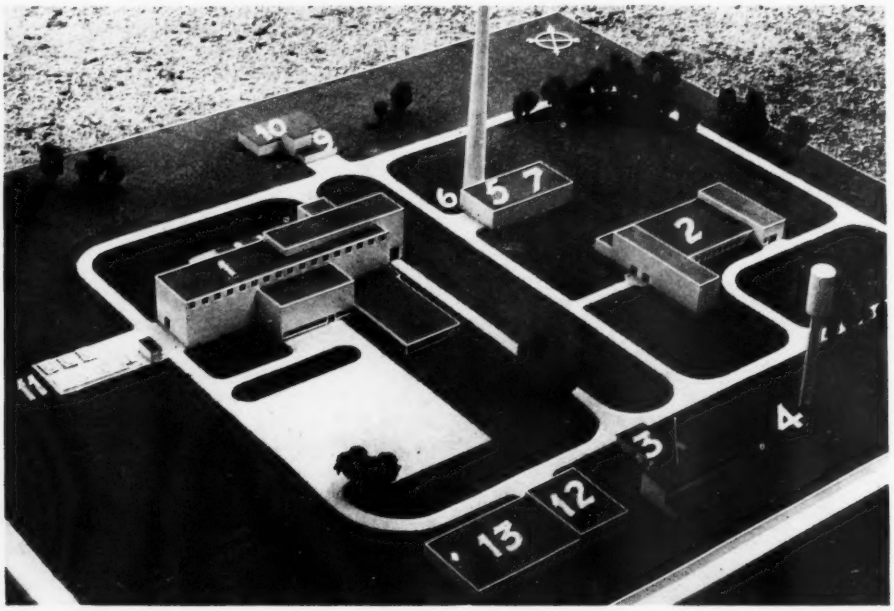
Limits Imposed

Although the plant will be designed to be versatile, there will naturally be limits to the type of fuel handled. Thus, only elements with enrichments of up to 5 per cent. U-235 will be accepted initially and with 10,000 MWd/t irradiation. A preliminary limit on size has also been made—100 in. in length (120 in. later) and about 7.7 in. diameter.

When they arrive at Mol the irradiated fuel elements will be transferred from their heavily shielded coffins to water-filled storage ponds. From here they will be transported, by remote control, to the cells where the canning materials are dissolved. The chemicals used for dissolution depend upon the type of cladding.

After being de-clad, the fuel itself is dissolved. For uranium and uranium oxide cores nitric acid will be used. For cores with molybdenum content, other chemicals will be used.

(*Below*) **Prince Albert of Liege, with Professor Leandre Nicolaidis, president of the Belgium Nuclear Energy Commission, and Dr. Erik Svenke, EUROCHEMIC chairman, at a recent ceremony to mark the start of work on the EUROCHEMIC plant**



Model of the Mol plant. Key: 1 Main processing building; 2 Research laboratory; 3 Steam and power plant; 4 Water tower; 5 Fan house; 6 Stack; 7 Air filter; 8 (*behind* 1) High level waste storage; 9 Waste treatment; 10 Waste storage; 11 Chemicals storage; 12 Mechanical workshop; 13 Materials storage

EUROCHEMIC is an international company formed by members of the Organization for European Economic Co-operation for undertaking chemical processing of irradiated fuel. Thirteen countries finance it and it has a capital of $21.5m. Agreement to form the company was reached in 1957 and the company came into official legal existence last summer. The 13 member countries are Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and Turkey. Before the company was formed preparatory work leading to the plans for the reprocessing plant was undertaken by an interim board of directors and a technical committee formed by OEEC.

At the end of the dissolution operation a solution containing the uranium, plutonium and fission products in the form of nitrates is obtained. This solution is pumped to the extraction unit where it comes into contact with a hydrocarbon solvent. The fission products are isolated, leaving the uranium and plutonium sections in separated portions of the nitric acid.

The uranium portion will finally be purified by means of silica gel adsorption. The procedure for final purification of the plutonium section, however, has not yet been developed. How it will be carried out depends upon the results of certain current investigations.

When the nitric acid solution leaves the first extraction process column it will contain the bulk of the fission products but less than 0.2 per cent. of the Pu and U. This effluent is concentrated to a small volume which is then stored in heavily shielded water-cooled stainless steel tanks.

Distillate from the fission products concentrator and acid effluents from other parts of the plant will be too active to be released. They will be concentrated in an " acid recovery " system and recycled into the dissolver vessel.

Other active effluents from the plant will be concentrated as " hot waste " and stored in steel tanks. Special precautions will be taken to ensure no accidental release of activity.

All equipment handling the radioactive liquors will be installed in shielded cells and operated by remote control. To prevent the escape of active particles from the cells to inactive sections of the plant, the cells will be kept constantly under a reduced pressure.

All process equipment will be fabricated from corrosion-resistant steels and all welds will be thoroughly controlled.

In addition to the precautions taken against the release of activity and the possibilities of contamination there will be the problem of criticality of fissile materials to contend with. This will be met by limiting the dimensions of the equipment (" geometrical safety ") and by keeping the concentrations of fissile materials low (" concentration safety ").

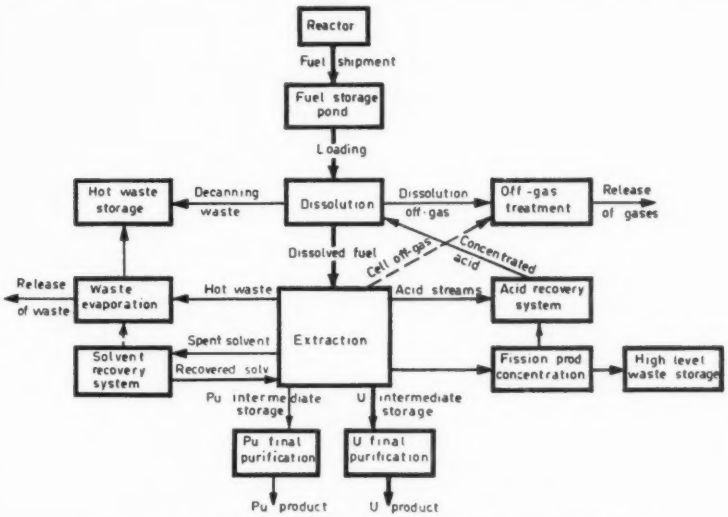
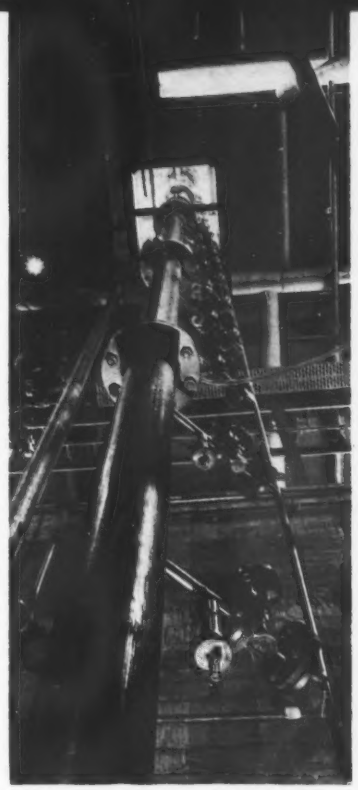


Diagram to show the various stages in the re-processing of irradiated fuel



The extraction column for Mol temporarily installed at a testing station

The research laboratory which is to be built in conjunction with the plant will be used for investigating all aspects of fuel reprocessing. One objective will be the development of alternative methods of reprocessing, though to begin with research will be directed towards improving current extraction methods.

By combining the results obtained in the laboratory, the improvements accomplished by inactive pilot plant work and the performance of plant tests under actual operating conditions, it will be possible not only to simplify and improve current methods of reprocessing but also to develop new methods. The overall effect will be to reduce reprocessing costs and to reduce the loss of valuable products. Also, the adaptability of known techniques. to a broad variety of fuel elements with different canning materials will be demonstrated and related procedures of waste treatment and " high level " storage will be improved.

The development work will also result in amended concepts for the construction of large-scale reprocessing plants which will have to be built when the nuclear energy programme has developed to a sufficient degree. Thus, EUROCHEMIC with its plant at Mol is not only meeting immediate needs but also preparing for the future.

Modest, but Important

India's Nuclear Programme

by A. E. Williams, PhD, FCS

COMPARED with the U.S.A., Russia and Britain, the nuclear energy programme in India is as yet a modest one. It is directed solely to power production, with a certain amount of isotope development, and has no nuclear missile branch; these activities being carried on under the direction of the Atomic Energy Commission. The first large-scale nuclear reactor, Apsara, of the swimming pool type, was put into operation in August, 1956, and has been operated for long continuous periods since that date.

Outside Russia, Apsara was the first reactor to come into operation in Asia. It was designed, engineered and built entirely by Indian technicians trained in Britain. The fuel elements, which embody enriched uranium, were supplied by Britain. Several types of isotopes produced in the reactor have been isolated and applied to Indian medical and biological work; while much research and experimental work has been carried out with the installation. In fact the main object of the reactor is not to provide any appreciable supply of electrical power, but to give experience to India's technicians in manipulating nuclear plant.

Centred at Trombay

At the present time, nuclear activities in general are based upon the Atomic Energy Establishment located at Trombay, some 15 miles from the centre of Bombay. The site of the Establishment, which covers an area of over 2,000 acres, is completely separated from the conventional industrial area by Trombay Hill on its west. Its eastern side lies on the upper reaches of Bombay Harbour. As the research and development centre for the application of nuclear energy throughout India, it houses not only extensive laboratories and workshops, but also a number of experimental reactors.

Of the latter the most outstanding is the Canada-India reactor, a 40 MW unit based on the design of the NRX (National Research X-perimental) reactor at Chalk River, Canada. Built under the aegis of the Colombo Plan, it has been designed and constructed by Canadian engineers with Indian engineers assuming responsibility for certain civil engineering work and all necessary auxiliary facilities and services.

Installation of the pile block started in September, 1958, and the reactor has just started operation.

It will be used for materials testing, isotope production, and has facilities for carrying out engineering loop experiments.

Six buildings adjoining the reactor are designed as laboratories for the testing and treatment of nuclear ores and minerals which are being recovered on a constantly increasing scale in various parts of India. A plant has also been erected for the concentration of heavy water which is produced at Nangal, in the Punjab.

Zero Energy Reactor

Another unit in the Trombay Establishment is a zero energy reactor which is used chiefly to yield information on reactor design. It facilitates the study of the effects of different lattices and the effects of different shapes and sizes of nuclear fuel elements.

Planned for installation is a 5.5 MeV accelerator and a 22 kV sub-station.

In addition to the actual experimental plants there are all the ancillary departments that are a necessary part of an atomic energy centre, such as an electronics section, an air monitoring division, and a health physics department. The number of technically qualified personnel employed at the Establishment, as to be expected, is constantly increasing and is already over 1,000. Including office workers and others, the total personnel is over 2,000.

Working in close co-operation with these people is an isotope section which is concerned with the preparation of isotopes for hospitals and research establishments. Research is also carried out at the Indian Cancer Research Centre on behalf of the Establishment.

The electronic section of the Trombay Establishment is concerned with the design and fabrication of electronic equipment for controlling the nuclear processes, and also for searching for suitable minerals for the nuclear programme. This section also operates in close co-operation with the health physics department in the development and maintenance of equipment for detecting radiation.

The work of the air monitoring division comprises control of radioactivity in air, water and foodstuffs. Tests are frequently made throughout the whole area of the Establishment, and in areas surrounding the site, to ascertain concentrations of radioactivity in these media. Improvements have been made by the air monitoring division on the conventional Geiger counter for the detection of radiation.

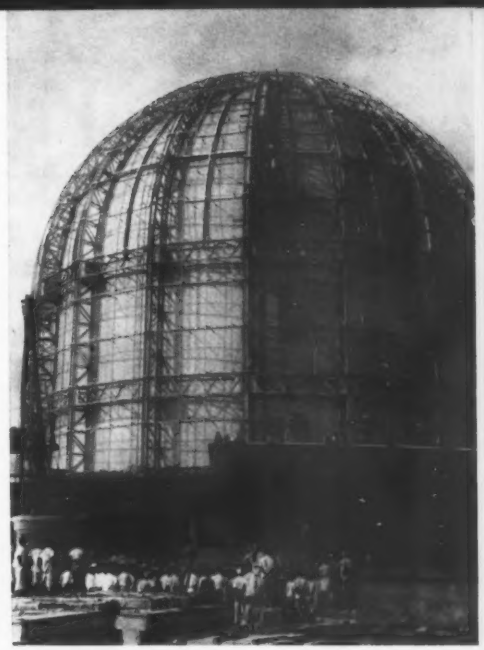
One of the tasks of the health physics department is to protect the Establishment's operators against radiation, and to supervise the decontamination centre, where workers may change clothes that have become irradiated before leaving the premises. This department is also concerned with the safety measures adopted in the discharge of radioactive waste.

Uranium Production

The pattern of India's reactors is made to match the nuclear fuels found in abundance within the country, uranium and thorium. At the Trombay Establishment the uranium metal plant produces pure nuclear uranium from concentrates of the metal delivered from various parts of India, the purified metal being applied to the construction of fuel elements for the various reactors in use there. A project is in hand for the isolation of plutonium.

Since thorium is plentiful in India, research is being concentrated on converting this economically to U-233, and India has built one of the world's largest thorium refining plants at Trombay. Thoria occurs in the monazite sands on the Kerala coast, and in Bihar, about 9 per cent. of thorium being present in the mineral. The raw mineral also contains a small proportion of uranium, which is sufficiently large to make monazite suitable as a source of uranium.

Indian scientists and engineers work in close collaboration with those in Britain, Canada and other Commonwealth countries, and if any scarcity exists in India, it tends to be in the field of technical know-how rather than in materials. While other countries favour graphite largely as a moderator, since it has a longer working life than heavy water, the latter is popular in India since adequate supplies are readily obtainable.



The Canada-India Reactor at Trombay which recently went into operation. A modified version of the NRX reactor at Chalk River, it has a thermal output of 40 MW and will be used for carrying out materials testing, producing radioisotopes and testing fuel-coolant system for power reactors

In 1952, the Indian Atomic Energy Commission erected a mineral processing plant at Alwaye, near Cochin, Travancore, which is operated by Indian Rare Earths, Ltd. The raw material is concentrated here before being sent to the extraction plant at Trombay, which represents Asia's first plant to produce nuclear grade uranium. It is proposed to set up another plant, capable of processing 500 tons of ore/day, in Bihar. Estimated reserves of uranium in India are placed at 30,000 tons, while thorium metal reserves are put at over 500,000 tons. There is sufficient nuclear fuel in India, therefore, to meet that country's requirements for a long time.

India can also supply her own moderating materials—graphite, heavy water and beryllium, all of which have been tried out at the Establishment. The Establishment has itself prepared suitable high density graphite from coke produced in India. Heavy water supplies are ensured from a plant at Nangal, while a plentiful supply of beryllium and its oxide is available in the country.

Beryllium and its oxide, owing to their relatively high cost and difficulty of manipulation, have not yet been as extensively applied as moderators when compared with graphite and heavy water; but circumstances in India are such as to change this. Highly industrialized countries need, for the most part, large power stations to supply electricity to high-density industrial areas. Less developed countries, such as India, on the other hand, are more in need of smaller stations, up to 50 MW, suitably dispersed to give a power supply to most areas. For reactors of stations with smaller outputs, beryllium and its compounds are ideal as moderators and, in fact, are more economical than graphite. Since India has plenty of beryllium, experimental beryllium oxide-moderated plants are being tried out before any large-scale plant is built.

Nangal Heavy Water

A plant to produce about 14 tons of heavy water each year will shortly come into production at Nangal, situated in the Punjab. The heavy water will be produced as a by-product of fertilizer manufacture, this being made possible through the collaboration of the Trombay Establishment with Nangal Fertilizers & Chemicals, Ltd. The plant is being constructed by the Linde Co., of West Germany, the electrical equipment being supplied by the English Electric Co., Ltd.

Profitable Process

The production of heavy water in this way is a profitable undertaking, for it depends on the availability of a supply of hydrogen. Since the heavy fraction is present to the extent of only one part in 7,000 parts of hydrogen, the amount of the latter still available for fertilizer processing is practically unaffected. An electrolytic plant operating on alkaline water produces practically pure oxygen and hydrogen. The oxygen is compressed into cylinders for hospitals, welders, etc., while the hydrogen is combined with nitrogen from an air separation plant in the required proportions to produce ammonia used in the manufacture of nitrogenous fertilizers. Deuterium separation from the hydrogen is effected by sufficiently compressing and cooling the latter to isolate the heavy fraction. As this fraction is

only a very small proportion of the total hydrogen, the cost of producing deuterium is due almost exclusively to the cost of compression and cooling.

Source Assaying

Mineral sources are exploited for the atomic energy industry by the Indian Atomic Minerals Division, which has trained technical men strategically placed throughout the country with the object of prospecting for nuclear minerals, and preparing and testing these. Temporary laboratories have been set up in many parts of the country for the radiometric assay of the samples which are obtained by drilling when necessary. The men operate from four subheadquarters, sited respectively at Bombay in the west, Calcutta in the east, Delhi in the north and Bangalore in the south. Different teams are engaged in surveying their respective areas by radiometric means, and where tests appear promising, extensive drilling operations are carried out to obtain core samples.

Some of these areas are prospected from aircraft flying at a height of about 450 ft and carrying highly sensitive detection apparatus. When the latter shows readings indicating promising material below, the area is examined in greater detail by using detectors in a motor truck. In this way large tracts of land can be surveyed in a relatively short period, and any promising site can be investigated by ground operations.

Other Minerals Found

These operations have, in addition to showing the amount of uranium and thorium available, led to the discovery of other nuclear materials. Zircon allanite, from which zirconium can be extracted, has been found in extensive deposits amongst the granitic rocks in the Andhra and Madras areas. Hafnium is associated with zirconium in some of these deposits. The mineral fergusonite, a source of yttrium, has been located in the graphitic rocks of the Madurai area, Madras. In the Udaipur region of Rajasthan extensive deposits of uraniferous ore have been found and are beginning to be exploited.

India is one of the world's largest producers of the mineral beryl, a source of beryllium. For use as a moderator, a plant has already been installed to produce beryllium oxide of nuclear purity. Because of the large tracts of land which have not yet been carefully prospected, it is likely that other deposits of nuclear minerals will be found in the future.

In countries such as Britain the nuclear power station is in competition with thermal power stations, and hydro-electric power is negligible; but in India there are extensive hydro-electric schemes. Current produced by hydro-electric plants in India is 20 times greater than the U.K. output from this source; 13 times as much as West Germany. Even the U.S.A. is only slightly ahead of India in the amount of electricity produced in this way.

Formidable Competitor

Many of the Indian dams have been constructed primarily for irrigation purposes, and the production of power is merely a sideline. Nevertheless, this method of generating electricity in India is of sufficient magnitude to compete with thermal power stations and any full-scale nuclear plants which may be erected there. The Indian hydro-electric plants have the advantage of bringing a supply of electricity to rural areas which are far from coal supplies, and this has enabled wide areas to be opened up to industry. A similar service could be provided by nuclear power stations in regions where dam construction is impossible. Oil fuel does not enter into the picture, for India has no oil and the authorities are opposed to the importing of oil.

Figures compiled by the Indian Atomic Energy Commission show that India is particularly well placed for the development of nuclear power stations, for its known reserves of uranium and thorium are the equivalent in energy value to over 30 times its reserves of coal. Apart from this, coal is more valuable when used other than as a fuel. It is a source of motor fuel, dyes and a whole range of chemicals, all of which are required in a country the industries of which are growing rapidly. This growth also increases the demand for electricity.

In 1953 India's total electricity supply was generated largely by the use of agricultural waste as fuel; coal accounted for only 18.3 per cent. of the total electricity produced. As the country becomes increasingly industrialized, there is less agricultural waste available, which means increasing the coal supply, or developing other means of power production.

The Future for Coal

India's coal production in 1951 was 34m. tons, and by 1956—at the beginning of the second Five Year Plan—it had risen to 40m. tons, and is planned to reach 60m. tons in 1961. This coal output will not, however, keep pace with the installed electrical capacity in the country. This capacity, during the decade 1940-1950, increased by 56 per cent.; while during the first Five Year Plan, 1951-1956, an increase of 60 per cent. took place.

By 1961, the end of the second Five Year Plan, the installed electrical capacity is expected to double itself. Such an increase in electrical consumption would require the coal output to be increased to 216m. tons/year. Since India's estimated coal output in 1961 will be less than 30 per cent. of that required to meet the electrical demand, other means of generating electricity have to be explored.

Cost Comparisons

The coalfields in India are by no means uniformly dispersed throughout the country, and this greatly increases the cost of coal in some areas. Over half of the total coal reserves are in the eastern corner of India, the states of Bengal and Bihar, and about 80 per cent. of total production comes from these areas. Prices at the pithead are around Rs.20/ton, and if its transit by rail was not subsidized, its price in distant areas would be over Rs.50/ton.. The development of additional hydro-electric schemes would not be economical, for the seasonal character of the rainfall involves the construction of extensive dams before water can be harnessed. It is these features which make nuclear power stations an attractive proposition in India.

In comparing the costs of an Indian coal-fired station with a nuclear station of 150 MW capacity, there are several factors to be considered. Assuming the real cost of coal is Rs.50 delivered to the station, the cost of electricity would be 5.3 hundredths of a rupee/unit, instead of 4.7 which is the figure when coal

(*Continued on page 424*)

A method for calculating fallout gamma radiation intensities within structures has been developed at the National Bureau of Standards. This method makes possible simple calculations of intensities within basements. Ultimately it should lead to improved theoretical treatment of radiation shielding properties

GAMMA RADIATION FALL-OUT

Measurement within Buildings

A METHOD for calculating fallout gamma radiation intensities within structures has been developed by scientists of the U.S. National Bureau of Standards working under the sponsorship of the Office of Civil and Defence Mobilization. The method makes possible simple calculations of intensities within basements, and it can be used to find, at the centre of a structure, the intensity of radiation entering through windows. With further refinement, it should provide an improved theoretical approach to the analysis of shielding properties of structures.

In general, for a simple structure, fallout radiation particles will be distributed uniformly over the roof of the structure and on the ground surrounding it. The radiation that reaches a detector inside can then be separated into that part coming through the walls and that coming through the roof. The intensity, or dose rate, of gamma radiation within the structure will depend mainly upon barrier attenuation (a function of barrier thickness and density) and geometrical attenuation (a function of the solid angle subtended at the detector by the barrier).

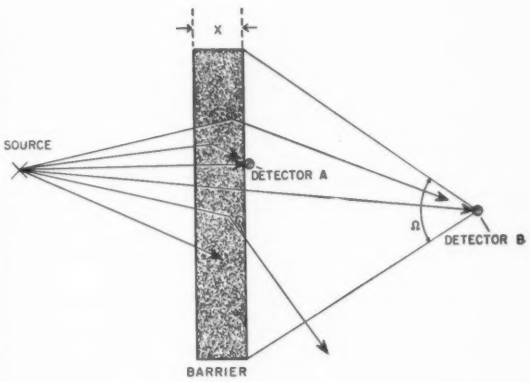
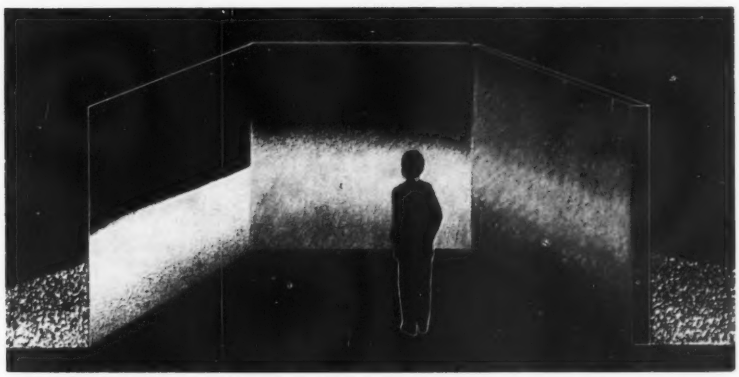


Diagram showing how the intensity of radiation received at a detector depends on barrier attenuation and geometrical attenuation. Radiation that is not absorbed in the barrier can reach the detector either directly from the source or after one or more scatterings in the barrier. The intensity at detector A, adjacent to the barrier, due to the fixed source on the left depends primarily on the barrier thickness X; the thicker the barrier, the lower the intensity. The dose rate at detector B, however, depends not only on the barrier thickness but also on the solid angle Ω subtended at the detector by the barrier. The geometrical attenuation is described in terms of this solid angle



This drawing illustrates how the distribution of radiation from fallout varies for walls of different thickness by showing how the radiation would look if it were visible to the eye. The radiation emerging from the thin wall on the left is the most intense. It is composed almost entirely of direct radiation from the radioactive sources on the ground outside. Consequently, almost all such radiation appears to emerge from the walls at points below eye level. The radiation emerging from the thick wall on the right is the least intense. Being composed almost entirely of radiation scattered at least once in the wall, it appears as a diffuse glow from points both above and below the eye. The radiation emerging from the walls of intermediate thickness (about 3 in. of concrete) in the centre is intermediate in intensity and distribution. The contrast in overall intensity between the thickest and thinnest walls would be much greater than shown here

The geometrical attenuation from sources on the roof can be described in terms of a single geometry factor. The dose rate from roof sources is then equal to the product of the barrier factor (barrier attenuation) and the geometry factor.

The geometrical attenuation of radiation from sources on the ground is somewhat more complicated because the direct radiation behaves differently from the radiation that has been scattered in the walls. The direct radiation reaches the detector only from below, while scattered radiation may reach it from either above or below. In the present method, the geometry factor for radiation from the walls is therefore separated into a direct and a scattered component.

The geometry factor for direct radiation has long been understood. Although the exact value of the geometry factor for the scattered radiation has not yet been calculated, it is known to lie within certain limits and to vary slightly with wall thickness. A suitable value may therefore be estimated.

Scattered Radiation

It is also known that the radiation emerging from very thin walls is

almost entirely direct radiation, while that emerging from very thick walls consists almost entirely of scattered radiation. For very thin walls, then, the dose rate is obtained as the barrier factor times the geometry factor for the direct radiation; while for very thick walls, the dose rate equals the barrier factor times the geometry factor for scattered radiation. For walls of intermediate thickness, the dose rate is obtained as the sum of the two products, each weighed according to the relative amounts of scattered and direct radiation.

Although several experiments have been performed to measure dose rates inside structures surrounded by artificially radioactive sources, the results of these experiments do not provide a proper test of calculations made by the Bureau's method because of complicating factors such as the presence of floors and inner partitions in the building.

Data suitable for comparison however were obtained from a controlled experiment made at the Army Chemical Warfare Laboratories using cobalt-60 sources distributed around a concrete blockhouse. The blockhouse is 12 ft long, 12 ft wide, and 8 ft high. Data were taken at ground level, 3 ft above ground, and 6 ft above ground at the centre of the structure for wall thicknesses of 4 in. and 8 in. of concrete. Although the data are somewhat limited, they verify the calculated trends.

Chooz N-Plant

Westinghouse Electric Corporation and two of its European Associates have received an award for a 242 MW nuclear power plant from Société d'Energie Nucléaire Franco-Belge des Ardennes (Sena), a group of French and Belgian utilities. The plant will be erected at Chooz, France, near the Belgian border and is scheduled for completion by 1965. W. E. Knox, president of Westinghouse Electric International Co., said that the Société d'Energie Nucléaire Franco-Belge des Ardennes after a thorough study of numerous proposals for various reactor concepts decided to select a closed-cycle pressurized water reactor plant that will be designed by Westinghouse.

Containment Vessels for BR II and BR III

(*Continued from page 407*)

inserted in the cylindrical wall, the residual stresses in the weld may, with the high values, reach a marked polyaxial character. Finally, the stresses resulting from excess internal pressure in case of an accident affect the entire steelwork of the pressure vessel and constitute a major source of energy, whose liberation would be alarming.

It was thus of prime importance to adopt a steel that would firmly guarantee against such an eventuality. Now, the Société Cockerill-Ougrée has been working for a number of years on a range of steels especially adapted for this purpose: these are the Soudotenax steels.

Soudotenax 41 steel was therefore selected for the containment vessels of the BR II and BR III. This steel is produced by the open hearth with very special care; the killing is carried out in a very careful manner; after rolling, it is suitably heated for normalizing; finally, all of it is examined by high frequency to discover any imperfections and to eliminate any doubtful plates.

No Special Additives

From the chemical point of view, it is characterized by a low carbon content (under 0.18 per cent.) which ensures excellent metallurgical weldability, and by very low content of sulphur (under 0.04 per cent.) and phosphorous (under 0.03 per cent.). Manganese content is of the order of 1 per cent. and silicon 0.2 per cent. There are no special elements added.

Failing stress is 26 to 31.75 tons/sq.in. and elastic limit is always over 16.5 tons/sq.in.

Favourable Properties

Its impact strength properties are particularly favourable and are an index of its remarkable resistance to brittle fracture. Its Mesnager impact strength across, at 68°F. in its natural state, is over 9 kg/cm²; in its aged state it still exceeds 8 kg/cm²; finally, Charpy V notch impact strength lengthwise at 14°F. (−10°C.) is guaranteed to be above 6 kg/sq.cm. Every Soudotenax plate undergoes such impact strength test.

The calculation, design and execution of the BR II and BR III vessels were carried out wherever possible in conformity with the Belgian standard NBN 121, the code of practice for the construction of apparatus subjected to pressure, the pressure vessel being considered a receptacle for compressed toxic gases.

Reference was also very often made to section VIII "Unfired Pressure Vessels" of the Boiler Code of the ASME (American Society of Mechanical Engineers); the interest of this regulation was that it had served as a basis for building in containers already, existing in the U.S.A.

All the major welds are of the full penetration type. Complete radiography was provided, which permitted the calculation formulae to use a very high coefficient of relative resistance, equivalent to 0.9.

An important point is the annealing of the welds. The *in situ* annealing of an airtight pressure vessel of the size we are considering here is scarcely conceivable in practice. It is for this reason that the American authorities, when they were confronted with this problem for the first time, were obliged to bow before material impossibility of the task and to forgo stress relief annealing, which is normally demanded for tanks under major pressures. They only did it with a certain number of reservations.

Rules Only Provisional

It should be stressed that the rules currently in force must be considered provisional. No code of practice exists at the present time appropriate to this class of structures and taking reasonable account of their peculiarities: the exceptional size, the contingent and rare character of their stresses, the absolute safety they must ensure, etc. A code of practice will have to be framed in the course of the next few years, and it appears that work on this has already started in the U.S.A.

(*To be continued*)

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RADIATION SAFETY AND CONTROL — II

THE FILM BADGE and ELECTROSCOPE

SIMPLE BUT COMPREHENSIVE TOOLS

by A. R. Gould

Royal Military College of Science

Subsequent to the publication in 1956 by the Medical Research Council of "Hazards to Man of Nuclear and Allied Radiations" and by the U.S. National Research Council of "Biological Effects of Atomic Radiation" increasing public concern precipitated the establishment of international recommendations for reductions in exposure limits. Further concern amongst the lay public followed the Windscale incident and was fanned by prevailing international interest in global fall-out. Reactions to the modern problems of atomic hazards have subsequently varied between two extreme views. The first regarded all things "atomic" with suspicion and the second extreme expressed vigorous protest and complaint against the reduced limits of safety legislation, which were supposed to be impossible to attain. It is hoped that the approach outlined in these articles will show that simple instrumentation can record all exposures to which the individual is subjected, and that adequate technical know-how exists for the formulation of practical procedures of radiation hygiene in order to limit exposures to well within any foreseeable reduction in permitted limits. Future experience with all kinds of radioactive and radiation hazards will undoubtedly substantiate these two fundamental concepts of sensitive measurement and convenient control of radiation exposure. When these methods are generally recognized then the problems of radiation safety should fall into their right perspective

IN determining the permitted levels of exposure in an establishment where normal work involves only an external radiation hazard, there need be no allowance for contamination, ingestion and inhalation exposures. Where all three hazards (*i.e.*, 1. radiation, 2. contamination and ingestion, and 3. inhalation) may give rise to dosage, they are usually assessed as incremental[1]. Permissible levels of external radiation, contamination and inhalation are then each properly reduced threefold. Thus, the permitted level for machine radiation dose-rates and sealed sources dose-rates in establishments where personnel may also be exposed to contamination hazards should be reduced to one-third. Indeed, it is usual safety practice in industrial hygiene to plan installations and work load, to 10 per cent. or 20 per cent. of a permitted hazard level, so that any increase is detected in time to minimize the possibility of prolonged exposure to high levels[2].

The effective usage of health physics instruments in measuring environmental hazard, and in assessing exposure to personnel, requires a comprehensive knowledge and practical experience of many technologies—electronics, radiological physics, statistics, physiology and bio-physics.

Each Hazard own Detection

Various problems in the day-to-day use of these instruments will be considered in this article. Last month it was shown that there are two forms of hazard, firstly, the "radiation" hazard and secondly, the hazard of "radioactivity" or "contamination" where open sources are manipulated with a possibility of entry into the body of radioactive matter.

Each type of hazard requires its own method of detection and measurement and these will be considered separately.

The external radiation hazard requires relatively simple dosage-recorders, such as the film badge, to measure the exposure to the individual, and the condenser chamber or electroscope dosimeter to record the integrated dose at various positions in the environment. Dose-rate meters are required to monitor and survey the site adjacent to the radiation source in order to estimate the efficiency of shielding and to investigate areas of hazard.

By now the film-badge of the white-coated nuclear scientist has become as familiar as the Geiger-counter. Such a small device with the deep psychological effects of a "magic tally" has naturally become the lucky charm of many establishments and is regarded as an infallible guide to the state of radiation hygiene whilst the health physicist is still discovering the limitations of its applications and the difficulties of assessment.

Nevertheless, the modern film badge[4] is a simple and valuable guide if used under carefully controlled conditions.

It has been shown[5] that the fog level of the PM1 film is mainly due to the background radiation and indeed the PM1 film badge will even demonstrate the differences between cosmic radiation and local backgrounds. If some films in each batch are kept inside an 8 in. iron safe for three to six months and others are kept in various "inactive" cupboards, offices and outside situations they will record differences of dose-rate level which agree very well with similar determinations using Geiger counters[6]. Hence a film badge can demonstrate any significant exposure to radiation above the local background (and even differences between localities) provided it is worn for a minimum of three months.

Check on Doubt

Experience over the last three years has shown[5] that a two badge system, three monthly and monthly in this case, has proved quite consistently incremental. This duplication of film badges has proved a valuable check on doubtful films, for where

only a single badge is worn, any inquest on doubtful films is rarely successful except in the most obvious circumstance. Where personnel wear two film badges the loss of a film badge or damage to a badge does not mean an " unknown dose " entry in the individual's record and co-relation between separate monthly badges and tri-monthly enables a cross check in cases of " mistaken identity." The two badge system will provide an accurate assessment of dosage from background levels up to the high level of 30 rads/period of wear. It is no longer sufficient to record " less than 20 mr/week " which implies an ignorance of dosage within occupational limits.

Storage Hints

Films should be stored before exposure in an iron safe with 8 in. walls, which will also house films withdrawn from service before processing, if care is taken to check contamination levels. It is usual practice to store film in any convenient cupboard without assessment of local background, which as these investigations show, accelerates the " ageing " effect of " background fog " and indeed, accounts for most of the increase in fog level with age (equivalent to some 120 to 300 mrads/year). This work indicates the necessity for care in storing film in avoiding granite, concrete, bricks, lead, etc.

The avoidance of " pseudo photographic exposure " by temperature, mechanical pressure or vapours should be routine in handling film badges. Even body heat and atmosphere will affect film fog levels when worn near the groin or abdomen[7] and some wooden storage boxes can affect the photographic emulsion due to the vapours of certain wood oils and resins. However, all these effects are an added safety factor for the false indication will not show *less* exposure than the individual has actually received.

Radium Favoured

Both in the U.K. and the U.S.A. radium sources are favoured as calibration standards for personnel monitoring films and in practice radium sources of some 100 mcs are used together with a " windmill type " or helical film display for various periods of exposure at varied distances. Such an arrangement occupies a large amount of laboratory space for long periods, gives unnecessary exposure to adjacent personnel, equipment and film stock and has an effect on nucleonic counters within 50 yd. As each film is exposed to only one dose, some 12 to 36 films are necessary to calibrate each batch of film developed. An ingenious alternative method[8] with a specially prepared β plaque can irradiate several areas of a single film at intensities throughout the range and is free from the disadvantages of the large area irradiation nuisance from γ sources.

Components of the newly designed film badge recently issued to employees of the Oak Ridge National Laboratory in America. (*Left*) The plastic frame and security identification photograph and insert. The little white packets in the centre are beta-gamma and neutron sensitive film packs. (*Top right*) The plastic back cover and clip. (*Lower right*) The largest metal piece on the plastic insert is an aluminium filter, and the other metal square is a cadmium-gold-cadmium combination filter. The narrow rectangular metal piece contains an impression of the employee's badge number. The protrusion at the bottom of the plastic insert is for future utilization of a chemical dosimeter. The badge meter location index number appears on the bottom of this chemical dosimeter section. Oak Ridge is operated by Union Carbide Corporation for the U.S. Atomic Energy Commission at Oak Ridge, Tennessee

Unfortunately these plaques require specialized equipment and skill in preparation and are not easily related directly to any accepted absolute standard. A small metal disc of natural isotopic uranium has proved[5] a convenient and practical standard source which is easily reproducible and should prove acceptable as an international standard.

The surface dosage from an " infinite " plane of natural isotopic uranium metal is now well established by calculation and measurement. The metal used is natural isotopic uranium sheet, aged to compensate for any differential distribution of UX1 and UX11 in processing and to establish a relatively stable surface (mainly U_3O_8).

The response of personnel monitoring films to beta fluxes of various

geometries has been investigated[9] and in particular the response to natural uranium sources. Such determinations have established that the shape of the characteristic curve for a given emulsion is effectively independent of the energy of the irradiating electrons or photons if they penetrate the complete emulsions of the monitoring film badge.

Variety is Possible

It is fortunate that the beta-particle energy spectrum shape remains substantially constant through an appreciable fraction of the maximum range, which enables the determination of exposures to beta irradiation (by film monitors) under a variety of circumstances from diverse sources (of the same isotope) and under different geometric conditions of distance and absorption.

Calibration to a standard β source may be used with a fair degree of accuracy in the interpretation of personnel doses acquired under many different circumstances from similar sources at different distances and shielding. Indeed the independence of the shape of the density *versus* exposure curve to beta-particle energy, or to photon energy, permits a valid comparison of personnel monitoring films exposed to any other source (even of unknown energy) giving an estimation of the relative magnitudes from a calibration curve to any standard β source.

Greater Accuracy

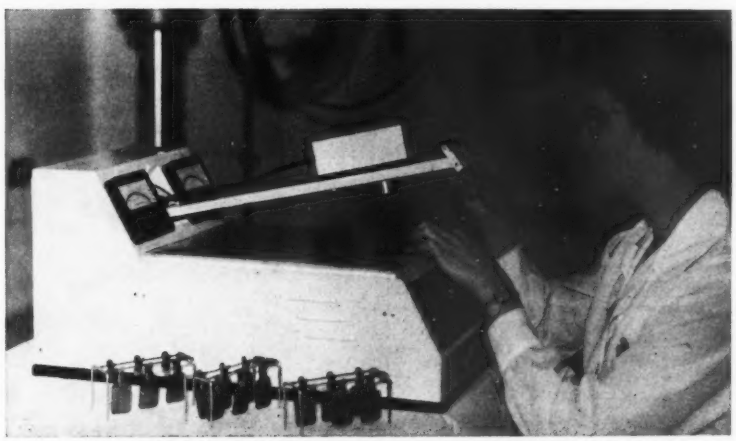
This enables relatively few films (each representing a whole range of exposures) to be included in every batch of films processed. By extrapolation, these reference standard calibrations, enable more accurate estimation of personnel exposures to different types of radiation[10].

With even elementary methods of processing these techniques ensure reliable interbatch comparisons with superior confidence to methods which rely on process control (by careful attention to precise conditions of time, temperature, agitation, chemical and physical nature of solutions) to achieve standardization. The demonstrated practicability and validity of uranium dosage calibrations should enable a simple method to be developed for an internationally accepted reference standard for personnel monitoring by photographic emulsions.

Similar Sensitivity

The fountain pen type—quartz fibre pocket electroscopes that are in common use have proved to be of similar sensitivity to the photographic films when exposed under similar conditions. Investigations over the past five years[5] have shown individual dosimeters to have electrical leakages of so low an order that long storage both in an iron safe and in various external situations of natural backgrounds has recorded differences entirely consistent with the previous work[6] with Geiger counters and subsequent experiments with film badges.

These pocket electroscopes have proved conveniently suitable as permanent " site dosimeters " when left in representative position around buildings housing linear accelerators, multi-curie sources and X-ray machines. They provide an immediate check should local conditions change rapidly, confirmation being obtained by the subsequent development of film badges.



Radiological densitometer designed and manufactured by Baldwin Industrial Controls, of Dartford, Kent, for the measurement of densities of film badges

Check without Trouble

Dosimeters may be checked as frequently as required without the need for processing or maintenance. For ultimate accuracy, it is of course, necessary to correct for temperature, pressure and gravity effects on fibre position and any rapid change in these environmental factors is not followed by the air within the sensitive volume of the dosimeter. However, the 500 mr FSD dosimeter may be relied upon within 15 mr of any reading without correction.

Each dosimeter should be initially tested for its natural electrical leakage by a three months exposure in an iron safe, following a calibration check for the energy of the radiations in use. This check should be repeated on an annual rota system so that for each dozen dosimeters there are nine in constant usage.

These two inexpensive monitors—film badge and quartz fibre electroscope—provide a comprehensive monitoring system of environment and personnel for many uses of machine and isotope radiation, without elaborate instrumentation. While small exposures of 1 mr to 5 mr on single occasions are not indicated by these, any repetition on several different occasions of even negligible exposures (in the microrad range) will be reliably registered and subsequent examination of the film badge or electroscope will indicate the integrated total dose. For many applications these two techniques will prove quite sufficient for continuous monitoring if implemented by an occasional survey to supplement the initial equipment and site survey. These surveys should be carried out with sensitive dose-rate meters to establish dose-rate around the site, during the various positions of source and shield, which may be encountered in normal working.

Increasing interest in dosage to non-occupationally exposed personnel has resulted in severely reduced mpls in different laboratories or workshops within the same establishment. Hence, there is an urgent need for instruments of greater sensitivity, responding from the

natural background levels *up to* mpls, in place of the widely used pistol grip ion-chambers which only respond *above* normal permitted levels.

In the past, much "mystique" has surrounded the use of pulse-forming detectors as dose-rate indicators, but health physicists are now becoming less reticent in their use as the limitations in the use of the ion-chamber techniques are disclosed by modern developments. Attempts have been made in the past to increase the sensitivity of ion-chambers by pressurization but resulted in apparatus (or response) too cumbersome for use as practical survey instruments.

If the source of radiation is known, then pulse counting devices, responding to a flux of particles or photons may be calibrated for health physics assessment of dose-rates from the natural background levels upwards.

Very Practical

Provided a number of basic physical principles are applied in the calibration, such an instrument will yield useful comparative results in many conditions and enable a practical assessment of hazards to be made. Care must be taken in the interpretation of such readings when applied to fluxes of radiation in a different energy spectrum. In practice, portable survey meters should be calibrated for the particular radiation emitted by sources or machines in the vicinity of the area.

Previous work of the author has shown that the response of tubes of unshielded G10H types or B12 type in a 1021 type shield may be used in radiological survey to assess dose-rates (from background levels up to levels above even the old maximum permitted levels) from single or distributed sources of either radium, cobalt-60, iridium-192, scandium-46, sodium-24 or caesium-137. In each case the pulse-rate of the tube (corrected for dead time and local background) was shown to be proportional (± 10 per cent.) to dose-rates indicated by extrapolation chambers or ion chambers, where only one gamma-emitter was distributed and hence, a calibration of corrected pulses/sec could be taken to correspond to dose-rate of corresponding micro-roentgens/hr for that emitter throughout the count range of the instrument.

The B12 tube removed from protective shield has given correspondingly reliable estimates of dose-rates about most β emitters. Each end of the tube requires an opaque coating to exclude light and care must be taken in using these comparatively fragile tubes unprotected.

Alternatives

Another form of pulse-counter—a modified scintillation counter—has proved to give consistent indication of γ dose-rate, under conditions of multiple scatter in various situations with many isotopes over the past seven years[5]. In these counters the photo-multiplier *current* was indicated on a simple galvanometer. An alternative indicator for portable equipment has been fabricated about a single transistor amplifier mounted behind a 5 in. scale micro ammeter (of 5 micro amps FSD) of the centre pole type.

The simple approach to the measurement of external radiation outlined above, has shown that this hazard can be effectively assessed with adequate precision and sensitivity. The current trend in contemporary radiation safety—of continuing reduction in permitted exposure levels may now be accompanied by sensitive exposure measurements at all levels.

Next month, Part III, instrumentation technology suitable for controlling contamination hazards will be dealt with.

References

[1]The cumulative concept of four causes of radiological exposures (whole body radiation, inhalation, ingestion and contamination) has been practised since the post-war effects of atomic energy release on the earlier concepts of the various X-ray and Radium Protection Committees recommendations re the inclusion of contamination and internal dosage, *e.g. NBS Handbook* 42 p.7.

[2]ICRP 1955 Supplement No. 6 of *Brit. J. Radiology* p.57, recommends a safety factor of 10 with respect of mpd in the design of radiological buildings and apparatus. ICRP 1957 *Acta Rad.* 48 (6) p.495 (IV) Dec. 1957 "ICRP expects a considerable factor of safety must be allowed in the design of protective devices and operating procedures" (Safety factor of 3 suggested). ARDARM, G. M., *et al* 1957 *Brit. J. Radiology* Vol. XXX p.600 No. 359. "It has been suggested that a dose level of, say, 30 mr. per week is a maximum which could be adopted...it is possible to work at about a tenth of this level." Radioisotope laboratory techniques by FAIRES, R. A., and PARKS, B. H., 1958 p.44 and 46 UKAEA investigates any weekly dose greater than 33 per cent.

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N-Energy in India

(*Continued from page 418*)

transport is subsidized. If the real price of the coal was Rs.40 at the station, the costs of generating electricity would be approximately the same as in a nuclear station.

The initial or capital costs would, however, be vastly different. The coal-fired station would cost about Rs.15 crores, against about Rs.25 crores for the nuclear station; thus showing a difference of around Rs.10 crores in capital outlay. There is also the cost of producing nuclear uranium for the station, which is estimated at Rs.5 crores, making a total of about Rs.15 crores over and above that for the coal-fired station. This big expenditure on the nuclear station would be partly offset by the difference in operating costs.

The coal-fired station would consume 450,000 tons of coal each year; the transport of which would require 1,200 rail wagons and 20 locomotives over a distance of 700 miles. This transport represents a capital investment of about Rs.2.2 crores. Such an amount of traffic also prevents the railway being used for other purposes, so making the costs of fuel transport well over Rs.2.2 crores. As long as the coal-fired station was in operation there would be no hope of reducing these transport costs. If one adds depreciation figures to the foregoing costs, it becomes apparent that nuclear power stations are still an interesting proposition in the industrial development of India.

'NUCLEARIST' writes . . .

NEWSPAPERS sicken me! Is there no good news available, without all the strikes, cold war, mistrust and industrial unrest? For a change I have read a few annual reports and found it a tonic. It seems that there are still a few pockets of sanity left in the world. M. Etienne Hirsch, addressing the European Parliament at Strasburg on the occasion of the presentation of the Euratom report, minced no words and did not flinch from pointing out the difficulties of Euratom. However, he looked upon these, not as reason for gloom, but as an earnest of confidence in the future.

A solution of the problems would speed the creation of the United States of Europe, towards which there is a strong urge among all member nations. The Euratom president hinted also at a European Council for Higher Education and Research, and regretted the lag in setting up missions representing the Communities in London and Washington. These Utopian ideals are a long way off, but on a road which we must tread, and a step towards a united mankind.

* * *

The most inspiring part of the UKAEA's 1959-60 Report is that concerning the happy collaboration with other nations, for which more money *must* be found. On the home front, there is encouraging progress, in spite of the slowing-down of the nuclear programme. The Dounreay fast reactor has justified our confidence, and may soon be the basis for civil units. Tests at Calder and Chapelcross show that fuel temperatures may be raised without loss of reliability. The Magnox system has proved itself. The AGR promises the best prospects for early competitive nuclear power in this country, and the HTGCR system looks increasingly promising as a power source for the 1970s.

* * *

Commendable restraint was shown in a comment, "A Cutback for Britain" in the Atomic Industrial Forum's *Memo*, in which attention is drawn to the British nuclear power programme deceleration. There was little sign of American gloating! Mention was also made of the lack of evidence of attainment of Russian objectives. But if the Joneses are pulling in their belts a little, there is less strain in trying to keep up with them, and the *Memo* hints at the possibility of an American easing-off, too. After all, the U.S.A. has its problems, just as we have, and both countries can learn from each other.

* * *

Another pioneer, Harwell's GLEEP, is having a rejuvenating face-lift. After 13 years of nearly continuous operations, it is being modernized. Its 35 tons of uranium bars and oxide pellets are being replaced by aluminium-canned natural uranium, and the instrumentation and control systems are being streamlined. GLEEP will soon be ready for action again, a veteran which does not intend to retire yet.

* * *

The USAEC has received the annual President's Safety Award. At the same time the eight men involved in the Y-12 criticality accident at Oak Ridge in 1958 are sueing the AEC for nearly $1m. as compensation for injuries which included impaired eyesight, weakness, stiff joints, sterility, and insomnia. A spokesman of Los Alamos Scientific Laboratory recently quoted no fewer than 16 criticality accidents in American nuclear history. Mr. G. L. Newbery, of the Amersham Radiochemical Centre, has pointed out that the U.K. history of atomic industry has not involved a single fatality by radiations. When we compare this record with the 1957 figures of 950 deaths from coal-gas, 140 from electric shock, 497 from railway accidents, and 5,550 on the roads, it is strange that the public still looks upon the atom as a killer!

* * *

Two more links in international relations are now forged. One is the cross-Channel power exchange system between Britain and France. This, when the transmission line is laid and in operation, will benefit industry on both sides of the Channel, the CEGB having placed a £610,000 contract for cables. Quite apart from the sentimental ties, there is also the important question of savings resulting from obviating the construction of additional plant as the power grids of the two countries take over heavier loads.

The second bond of union is already under way at Mol, Belgium, where construction has started on the plant for Eurochemic. This OEEC collaborative effort for processing irradiated fuel for 13 European countries will ensure maximum benefits for all, besides providing good chances for those industries undertaking the construction and operation of the plant.

* * *

Some years ago, when the toxic properties of beryllium were first realized, there were many industrialists who fought shy of it. Now, however, it is becoming of importance, especially for nuclear fields, where its low density and low neutron absorption make it excellent for neutron reflectors. It is somewhat surprising, then, to find that production has fallen steadily since 1956. For the years 1956, 1957, 1958 and 1959, world production was 12,900, 11,300, 7,400 and 7,300 short tons. In North America, South America, Europe, Asia and Africa, the production has fallen, only Australian sources maintaining their small annual output of about 400 tons.

* * *

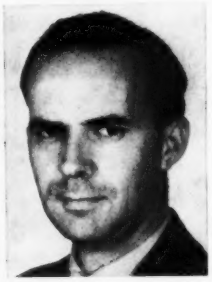
In a foreword to a new book, "Atomphysik in der Schule," Prof. Dr. Karl Hahn has stressed the urgency of introducing nuclear physics into schools, even though present syllabuses are crowded. Once again, it is the quart in the pint pot! Yet there is no justification for leaving out twentieth-century physics, just because a syllabus is crammed with earlier stuff. From a recent survey undertaken by the Institution of Nuclear Engineers it is clear that there is still much to be done towards practical work, even in some of the higher nuclear courses. Much could be achieved by disseminating experience and know-how on simplified experiments and equipment, and the Institution's work in this direction should be very valuable. Especially on the Continent, students go through a course with hardly any work in the laboratory. Can the different tradition in Britain be the reason why we have produced more than our fair share of Nobel Prize-winners?

PEOPLE

DR. E. A. VICK, OBE, deputy director of the Atomic Energy Research Establishment, Harwell, has been appointed director; **DR. R. SPENCE,** CB, FRS, chief chemist, has been appointed deputy director and **MR. L. GRAINGER,** head of the metallurgy division, has been appointed assistant director, with special responsibilities for applied research. **SIR BASIL SCHONLAND,** CBE, FRS, continues as director of the Research Group, of which AERE, Harwell, is a part.

MR. D. A. F. DONALD, chairman and managing director of the National Cash Register Co., Ltd., has been appointed chairman of G. A. Harvey & Co. (London), Ltd. He succeeds **SIR THOMAS OVERY** who has resigned the chairmanship on medical advice, but remains a director.

DR. WILLIAM McKIRDY DEUCHARS, a senior scientific officer at the Atomic Weapons Research Establishment, Aldermaston, has been awarded a Selby Fellowship by the Australian firm of Selby



Dr. W. McK. Deuchars

Brothers. The Fellowship will be tenable at the Australian National University, Canberra, and Dr. Deuchars will work for one year under Professor Titterton. Dr. Deuchars was born in Dumbarton, Scotland, in 1930, and was at school there. He took his BSc at Glasgow University and subsequently did post-graduate research in low energy nuclear physics which led to a PhD in 1955. He joined the Nuclear Research Division of the AWRE on leaving Glasgow. Here, his principal interests have been the study of neutron and charged particle reactions.

DR. ROBERT L. LOFTNESS, manager of applications engineering for Atomics International, a division of North American Aviation, Inc., has been appointed commercial director of Dynatom, the company formed jointly by North American, Société Alsacienne de Constructions Mécaniques and Chantiers de l'Atlantique (Penhoet-Loire) to design, build and market nuclear reactors in France and the French Commonwealth. Dr. Loftness first joined North American in 1949. He served as a scientific attaché at the American Embassy in Stockholm from 1951 to 1953 and returned to the company in 1953. During his assignment in Sweden he reported on many European scientific conferences and followed the progress of scientific developments in Scandinavia and Western Europe. He has also been associated with the University of California Radiation Laboratory and the Naval Ordnance Test Station at Inyokern, California. Dr. Loftness will be moving to Paris to assume his new duties this summer. President of Dynatom is **VICE-ADMIRAL D'ESCADRE JOSEPH-AUGUSTE LAURIN** and vice-president, **ROGER JULIA,** director general of SACM. **J. L. ATWOOD** and **CHAUNCEY STARR,** of Northern American, are directors of the company, together with **JEAN PINCZON** and **PIERRE LOYGUE,** of l'Atlantique.

MR. ROBERT D. WYLIE, has been appointed manager of quality control for the manufacturing department of the American Babcock & Wilcox Company's boiler division. Educated at Michigan University, Mr. Wylie joined Babcock in 1948 as a metallurgist in their quality control department. In 1957 he became chief metallurgist and in 1959 was appointed assistant manager of quality control.

Sir Donald Perrott, KBE, who has retired as member of the UKAEA for Finance and Administration

SIR LESLIE GAMAGE, MC, chairman of the General Electric Co., Ltd., has relinquished his duties as a managing director of the company. At the end of the year he will also give up the chairmanship, which he has held for three years. Another retirement from the board recently announced is that of **MR. J. J. GRACIE,** CBE, general manager of the Witton works. Aged 61, Mr. Gracie has been with GEC since 1921.

MR. J. B. ADAMS, the first director of the new United Kingdom Atomic Energy Authority's thermonuclear research laboratory at Culham, Oxfordshire, will take up his duties in October against a background of world-wide respect and admiration. Honours have been conferred on him for his work on the 25 GeV proton synchrotron at Geneva and it is of no little significance that he has been appointed director-general of CERN in succession to the much-respected Dr. J. J. Bakker, who died in an aircraft accident last April. Born in England in 1920, Mr. Adams worked in atomic energy in its early days. In 1946 he went to Harwell where he worked on the design and construction of a 110 in. synchrotron. Later he devoted his energies

Mr. J. B. Adams at CERN

to the development of high frequency klystrons with a 20 MW pulsed output for powering linear accelerators. In 1953 he was released from his duties in England to help design and build the 25 GeV proton synchrotron at CERN and was in the following year appointed director of CERN's proton synchrotron division. For his work on the world's largest synchrotron he was recently awarded the title of Doctor Honoris Causa by Geneva University and later received from the University of Giessen, Germany, the Roentgen Prize. Following the death of Dr. Bakker he was appointed the acting director-general of CERN and then in July full director-general. This appointment will continue until August 1st, of next year and, under an agreement between the UKAEA and CERN, Mr. Adams will undertake his duties in this capacity concurrently with those as director of the Culham laboratory.

MR. EGER V. MURPHREE, president of Esso Research & Engineering Co., the scientific affiliate of Standard Oil Co. (New Jersey), has been elected a director of the Atomic Industrial Forum, the American association of the nuclear industry. Mr. Murphree has been a member of the General Advisory Committee of the US Atomic Energy Commission since April, 1957. He is a member of the American Nuclear Society, the American Chemical Society, the American Petroleum Institute and the American Institute of Chemical Engineers.

Westminster talks about...

by Peter Lewis—Our Parliamentary Correspondent

MEMBERS were strangely quiescent upon matters of nuclear energy during the month. Whether this was in apprehension of Ministerial changes, or due to a let's-come-back-to-it-after-the-hols outlook, remains a mystery. But quiescent they were, and even when **Mr. Roy Mason** (L., Barnsley) asked the Secretary of State for Foreign Affairs whether any further consideration had been given to closer association between the Atomic Energy Authority and Euratom, **Mr. Profumo** replied that he had nothing to add to the answer he had given Mr. Mason exactly one month before. Mr. Profumo's previous answer indicated that the Secretary would be ready to consider the proposal that Britain should join Euratom as part of a wider settlement in Europe. Since when, Mr. Profumo has had the distinction of being the only junior Minister to be promoted, in the recent reshuffle, and is now the new War Minister.

N-deceleration

The now classic phrase "Deferment of acceleration" used to describe the cutting down of Britain's nuclear energy programme, prompted Mr. Mason to ask the President of the Board of Trade, to what extent he estimated that joining Euratom would offset this deferment. Mr. Mason was also anxious about the extent to which the industry's manpower would be run down. Replying, **Mr. John Rodgers,** the Parliamentary Secretary to the Board of Trade, said there would be some compensation for the rephasing of the nuclear power programme by the increase in the conventional programme, and the President was now discussing such adjustments with the plant manufacturers. Mr. Rodgers considered it unlikely that joining Euratom would materially affect the size of the industry during the next few years.

ZETAs I and II

Up again and asking questions, was Mr. Roy Mason, this time on the subject of thermonuclear power, and what might be regarded somewhat unkindly by the lay man, as that old has-been ZETA. Mr Mason asked the Minister of Education as representing the Minister for Science what had been the cost to date of experiments conducted to develop thermonuclear power in ZETA I and ZETA II, respectively; what progress was being made; and what were the prospects of thermonuclear power being successfully developed for peaceful purposes. **Sir David Eccles** replying for the Minister for Science, said that the capital and operating expenditure on ZETA I and its modifications up to June, 1960, had totalled about £2,600,000 including £460,000 for design studies and development work for ZETA II and other future systems. No capital expenditure had been incurred on ZETA II because the design studies and development work together with experience on ZETA I, had shown the necessity for an Intermediate Current Stability Experiment (ICSE) for plasma stability studies, and this was now in active preparation.

N-trawlers?

The perennial topic of nuclear propulsion was introduced again by **Mr. Hector Hughes** (L., Aberdeen N.) who asked the Minister of Transport whether, in addition to his plans for nuclear tankers of 65,000 tons, he would consider inviting tenders for smaller nuclear ships with particular reference to ships in the fishing industry, including factory ships and trawlers. **Mr. Marples** replied that it was too early to consider that step for any but large ships. Not content, Mr. Hughes then asked the Minister if there were any scientific objections to such an application and, if so, would he specify what they were. Mr. Hughes pointed out that fishing trawlers represented one of Britain's major industries and asked the Minister if he did not agree that it was wrong to discriminate against the fishing industry in this way. Mr. Hughes ended by requesting the Minister to give his whole attention to this very important suggestion.

Mr. Marples at once agreed that it was an important suggestion, and added that he was bound to say that if nuclear power was to be applied to merchant ships it must be competitive in order to survive, and therefore, in the early stages, technically it would be necessary to apply it to large ships and await results.

Mr. P. H. B. Wall (C. Haltemprice) wanted to know how soon after the closing date for the receipt of tenders the Minister expected to place an order for a nuclear-propelled merchant ship, and to what degree the Royal Navy would assist in her development. Mr Marples replied that the highly complex task of assessing the tenders would take several months.

Uranium Stocks

In his now familiar role of Minister for Science, Sir David Eccles was asked by **Mr. C. Osborne** (C., Louth) how much money would be lost by the Atomic Energy Authority in carrying unused stockpiles resulting from the slow-down of the atomic power programme, and over how many years, and would the Minister make a statement. Sir David stated that the slow-down would result in the Authority carrying large stocks of uranium. The cost of storage was small, but it was estimated that the annual interest on the capital locked up in the additional stocks, might amount to several million pounds. Present estimates indicated that the Authority's current and prospective uranium supplies might last for about ten years; their exact duration would depend upon factors which could not be estimated accurately at the moment.

The next day, after debates on Space Research, the Hotel and Tourist Industry and Juvenile Offenders, which were in no way connected with each other, the House adjourned until October 25th.

U.K.A.E.A. Sixth Annual Report

Highlights in the year April, 1959–March, 1960

Money Matters: The Authority have budgeted for an expenditure of £93,293,000 during the year 1960-61, compared with a net expenditure of £92,433,010 during 1959-60. Balance sheet of the Authority on March 31st, shows that value of the assets held by the Authority totalled £450m. This is three times the amount of assets held when the Authority was set up in August, 1954.

Calder Hall and Chapelcross: Output of electricity from the Calder Hall and Chapelcross reactors, all of which had come into operation by end of year, rose by over 300 per cent. during the year under review; that from Chapelcross, in fact, represents some 20 per cent. of the base load of the South of Scotland Electricity Board. Production of fissile material also increased, by 40 per cent.

Springfields: Most of the new Springfields uranium production and fuel assembly plant was in operation by the end of the year in preparation for the start-up of the civil power programme. When running at full capacity this plant will be capable of producing over 300,000 uranium elements a year.

Fuel Reprocessing: The fuel reprocessing plant at Windscale continued to operate satisfactorily during the year. Throughput of elements increased by 30 per cent. and modifications in operating procedure reduced activity released from the factory by about 15 per cent.

Gas Cooled Reactor Developments: Considerable work was undertaken in developing improvements to be incorporated in the commercial nuclear power stations under construction. Construction of the prototype advanced gas cooled reactor (AGR) at Windscale continued and design studies were carried out to optimize this system for large stations. Progress was made in the setting up of the DRAGON high temperature gas cooled reactor project at Winfrith under the auspices of the OEEC. ZENITH, the zero energy reactor designed to support work on the HTGCR, was put into operation.

Dounreay Fast Breeder: This reactor went into operation last autumn and reached criticality in November. It was then run at low power (100w), but at high temperature, in order to test reliability of components and safety devices. In general, experience obtained in start-up operations confirmed the Authority's confidence in the potentialities of this system.

Steam Generating Heavy Water Reactor: Design studies and investigations of heat problems involved were made on the possibility of developing a reactor in which light water used as coolant is evaporated in the reactor core itself instead of in heat exchangers, and so eliminate the need for the latter. One of the problems involved is the coping with two different types of water in the core. A decision whether to proceed with the construction of an experimental reactor of this type will depend upon the results of current investigations and on the availability of manpower and cash.

Marine reactors: Technical assistance was given to the Admiralty on safety aspects of the *Dreadnought* submarine. The Authority is also contributing to the evaluation and examination of systems designed for merchant vessels.

Nuclear Physics Research: Much work was undertaken with the Authority's particle accelerators. Last November a new 30 MeV linear accelerator was brought into operation when the Neutron Project Laboratory started work.

Radioisotope Research: Work has continued at the Wantage Research Laboratory on the application of radioisotopes, especially in industry. Further work has been done on the use of gamma radiation for sterilization and other applications, and during the year a pilot scale irradiation plant with a 120 000 curie source was started up

Controlled Thermonuclear Reactions: Experiments related to the design and construction of the Intermediate Current Stability Experiment (ICSE) were continued. At the same time work proceeded on a number of other plasma physics experiments. Construction of the Culham laboratories, to become the centre of the Authority's thermonuclear work, started.

Uranium Supplies: Due to the slowing down of the nuclear power programme and to reductions in initial fuel loadings of reactors which have followed improvements in the design of the magnox reactor, the Authority's commitments under their long term uranium contracts are greater than their immediate requirements. Arrangements were made during the year to "stretch out" the current contracts.

Health and Safety: The Authority established a new branch responsible for advising the Authority on the formulation of their health and safety policy and to disseminate this policy for application by heads of groups and establishments. They also have to apply this policy to the assessment and inspection of reactors, plant and laboratories and to provide a focal point from which the Authority's external relations in the health and safety field will be conducted. A wide range of health and safety problems was continued to be studied during the year.

Commercial Operations: During the year the Authority's revenue from the sale of fuel elements, radioisotopes, graphite, electricity and from fees for consultancy and training work and licence agreements amounted to £20m. The sale of isotopes through the Radiochemical Centre brought in £1.1m., an increase of 25 per cent. over the previous year.

The report is available from the Stationery Office price 5s. A glossy shortened "popular" version is also obtainable, price 2s. 6d.

NUCLEAR NOTES

C.E.G.B. Surveys

Following investigations by the Central Electricity Generating Board for possible nuclear power station sites in Anglesey, three suitable sites have been found at Wylfa, Carmel and Trefadog in the north-western part of the Island. The Wylfa site is on the north coast, about 1½ miles west of Cemaes Bay; the Carmel site is further west, almost at the north-western corner of the island and the Trefadog site is on the west coast about four miles south of the Carmel site. The Generating Board have considered these sites together with that at Edern on the north coast of the Lleyn Peninsula and they have come to the conclusion that when a second nuclear power station is required in North Wales they would propose to seek permission to the development of the Wylfa site.

Project Extended

The International Halden boiling, heavy water reactor project in Norway is to continue 1½ years longer than originally planned. Under the terms of agreement signed by the participating organizations in June, 1958, the joint programme of research and operations was scheduled to run for three years. Halfway through the three-year period it became obvious that in order to achieve the objectives of the agreed programme an extension would be necessary. Total cost of the project is now fixed at just under $6m., for which additional funds of $3,137,500 will have to be found by the participants to cover the extra year and a half. Taking part in the project are the Norwegian Institutt fur Atomenergi (owners of the reactor installation), Austria, the Danish Atomic Energy Commission, Euratom, the Finnish Atomic Energy Commission, AB Atomenergi of Sweden, Switzerland, and the U.K. Atomic Energy Authority.

DRAGON Reported

The first annual report of the OEEC High-Temperature Reactor Project (the DRAGON project), has been published by the European Nuclear Energy Agency. The report covers the period from the start of the project on April 1st, 1959, until March 31st, this year. Highlights are the very rapid build-up of project staff, the considerable progress made in the first year (the design of the reactor experiment to be built at AEE Winfrith, has been finalized and construction work has started), and the negotiation of an agreement with the U.S. Atomic Energy Commission for a full exchange of information between the project and a similar project at Peach Bottom in Pennsylvania. The report is in three sections of which the first (Introduction and Organization) surveys briefly the historical background and structure of the project, and gives a general statement on its present status, including finance. The remaining two sections cover, in considerable technical detail, the first year's progress in research, development, and reactor design and construction. It is stated in the Introduction that this has been done because the Board of Management feel that " this first report should be somewhat more extensive in scope than future annual reports and should be published so that a full picture of the DRAGON project might be made available to a broad public."

Italian Ship Plans

Representatives of the Comitato Nazionale per le Ricerche Nucleari, the Fiat Co., and the Ansaldo Shipyards have submitted to the Euratom Commission a study, research and development programme for a nuclear-powered ship. This programme provides for the setting up of a project for a 52,000 ton tanker, equipped with a water-type reactor of advanced design, to be developed in Italy. It is expected that Euratom will provide technical and financial aid for the execution of this programme, which will take two years and will be of potential interest to the nuclear industries of all the Euratom countries.

Calder Concrete Wet

Little drying of the concrete in the reactor shielding at Calder Hall has taken place, it is stated in the 1959 annual report of the Building Research Centre Station. Also, the concrete temperature is lower than had been expected. These observations have been made during the course of long term investigations being undertaken by the station in collaboration with the U.K. Atomic Energy Authority Industrial Group into the effects of temperature, drying shrinkage, creep and radiation on large concrete masses used for biological shielding. The station is also making studies into the performance of the concrete monoliths used to support the magnet sections of the 7 GeV proton synchrotron at Harwell. In addition, measuring instruments have been placed in the biological shielding installed at the Berkeley and Bradwell nuclear power stations.

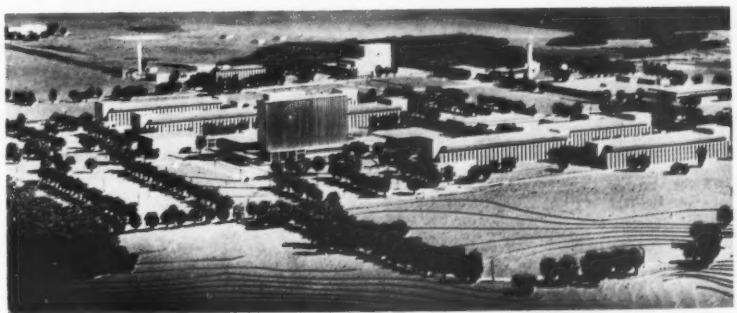
Apprentices Abroad

Six apprentices from the CEGB were recently the guests of Electricité de France for a fortnight when they visited the National Trade School at La Perolliere, several hydro-electric stations, a cable manufacturing firm at Lyons and other places of interest. The visit was on an exchange basis.

Effluent Advice Given

Simon-Carves Ltd., and Monsanto Chemicals Ltd., have formed a joint industrial effluent treatment advisory service for providing general advice on effluent problems, on-site and laboratory investigations on the treatment of specific effluents, recommendations and design data for effluent treatment processes and plants, and continuing advice on the operation of commissioned treatment plants. In addition the full engineering and contracting organization of Simon-Carves Ltd., is available for the actual construction, installation and commissioning of complete effluent treatment plants. The service which is at the disposal of industrial organizations and public authorities is administered by Simon-Carves Ltd., from their headquarters at Cheadle Heath, Stockport, Cheshire.

New U.S. Physics Research Centre



Model of the new National Bureau of Standards laboratories to be located at Gaithersburg, Maryland. Work on the first construction stage will start during the next 12 months. One of the first buildings to be built will be a radiation physics laboratory and it will house a new high energy linear accelerator. A 180 MeV electron synchrotron, 50 MeV betatron, and 2 MeV positive ion Van der Graaf, already operated by the Bureau, will be moved into the new building. Contract for the construction of the new linear accelerator has gone to the High Voltage Engineering Corporation, Burlington, Mass.

NUCLEAR NOTES

I.A.E.A. Report

A steady growth in the provision of technical assistance to Member States, in the training of scientific and technical personnel, in technology for the use of radio-isotopes, in the establishment of standards and measures for radiation protection, and in the exchange of technical information, is noted in the annual report of the International Atomic Energy Agency. The document also reports on the Agency's recent work concerning nuclear power technology and economics, and formulation of safeguards against military diversion of nuclear materials. The report predicts that the Agency's operations in the coming year will " continue in the main along the lines now established with some expansion, particularly in the domain of technical assistance and scientific information and support."

G.E. Reactor Critical

Venezuela's first nuclear reactor, built by U.S. General Electric for the Venezuelan Institute for Scientific Research (IVIC), recently reached criticality with 28 fuel elements. Following instrumentation calibration, systems-components checkouts, and low-power tests the reactor is due for formal dedication in September. The reactor will be utilized for investigation of Venezuelan medical and bio-chemical problems and as a basic research tool. This reactor, which will furnish 3,000 kW of heat, is one of a number of " open pool " research reactors designed, built and supplied by General Electric throughout the world.

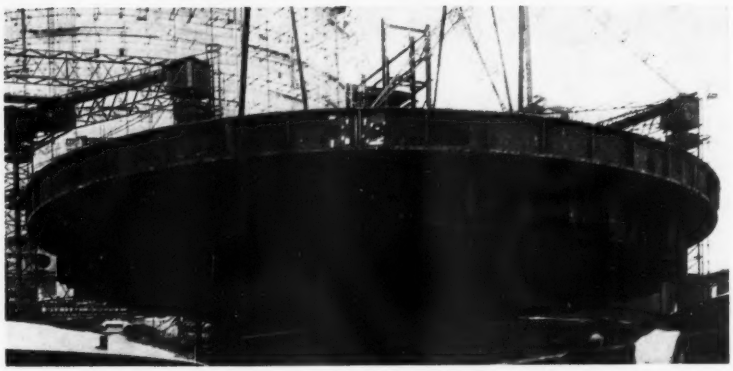
Stockholm Exhibitors

In addition to the United Kingdom Atomic Energy Authority, some 15 British manufacturers will be represented at the Instruments and Measurements Exhibition in Stockholm, September 10th-17th, 1960. Included among them will be Plessey Nucleonics Ltd. Their stand will be entirely devoted to a display of products and photographs showing how the company is playing a major role in the design and manufacture of burst fuel element detection systems, health monitors and other types of nucleonic instruments. Focal point of the display will be a moving model of the latest Mk. III precipitator.

Israeli Research

A new research department—the Department of Nuclear Induction—is being added to the Weizmann Institute of Science, in Israel, bringing the number of departments to ten. It will be headed by Professor Shaul Meiboom, who is now on leave and working on a research grant in the U.S. Bell Telephone Co.'s research laboratories. Meyer W. Weisgal, chairman of the Institute's executive council, said that the elevation of the Nuclear Induction Laboratories, headed by Professor Meiboom for the past six years, to the status of a department was a tribute to the high standard of his work in the field of experimental physics.

Shots from Hunterston



(*Above*) **The core support grid being lifted from its fabrication area for placing into reactor A at the Hunterston nuclear power station being built by the General Electric Co., for the South of Scotland Electricity Board.** (*Right*) **CO_2 gas coolant distribution piping being placed into position on the inner shield of Reactor A**

Seawater Conversion

Professor J. P. Baxter, chairman of the Australian Atomic Energy Commission, has stated that seawater converted to drinking water by means of nuclear energy would soon be supplied to some Australian households. He forecast that the port of Geraldton, Western Australia, would be Australia's first town to install an atomic conversion plant. The fresh water produced would cost about 3*s.* to 4*s.*/1,000 gal, which was little above the cost of normal supplies but too expensive for irrigation purposes.

Food Info. Centre

The world's first international information centre for food irradiation has been set up as a result of a contract signed between the OEEC European Productivity Agency and the Centre d'Etudes Nucléaires at Saclay, France. **M.** Pierre Lévèque has been appointed director of the Centre, which will be set up at Saclay. The functions of the Centre include the preparation, publication and distribution of a quarterly international newsletter on food irradiation in both English and French. The Centre will also serve as a point of contact between the scientists, food technologists and the governmental and industrial circles interested, and will encourage closer international co-operation in the development and application of knowledge in the field for food irradiation. The contract, which has been signed for an initial period of two years, provides for the payment by OEEC/EPA of a sum of 32,000 new francs to cover printing and translation costs and other incidental expenses.

Uganda Search

During the next few years an intensive search for minerals is to be undertaken in Uganda reports Barclays Bank DCO. It will cost an estimated £216,000, and of this sum an aerial survey alone will cost approximately £112,000. The Bank states that £95,000 of this will be provided by the United Nations Special Fund and the balance will come from Uganda. Other investigations are being made by two members of the United Kingdom Atomic Energy Authority who are looking into the beryl deposits in Kigezi and Ankole, in Western Uganda.

B.G.E.C. = C.E.G.B.

The Engineering Group of The General Electric Co., Ltd., announces that it has reorganized its representation at the company's branches in Great Britain under five area chief engineers. This has been done in order that the four areas in England and Wales shall conform more closely to those of the Central Electricity Generating Board's generating divisions and area boards. The territories covered by the South of Scotland Electricity Board and the North of Scotland Hydro-electric Board will remain the responsibility of the Scottish Area chief engineer.

NUCLEAR NOTES

N-Control Tribunal

The first meeting of the tribunal established under the OEEC Convention on Security Control in the field of nuclear energy was recently held. The Security Control Convention, which is designed to ensure that joint nuclear facilities developed with the help of the OEEC's European Nuclear Energy Agency are used exclusively for peaceful purposes, has been signed by all OEEC member countries. The tribunal consists of seven independent judges appointed for five years by the OEEC Council. Its main purpose is to hear and decide appeals both by private undertakings affected by the control measures and by governments against decisions taken to implement the control. Its competence can also be extended to any other matter relating to the joint action of member countries in the field of nuclear energy, and this has already been done in the case of disputes regarding the Eurochemic and Third Party Liability Conventions.

Uranium Oxide Sales

From South Africa, Barclays Bank DCO reports that the vice-chairman of the Atomic Energy Board, Dr. T. E. W. Schumann, has drawn fresh attention recently to the fact that South Africa's contracts for the sale of uranium oxide to the Combined Development Agency at a price of 84s./lb would lapse during the years 1964/66. In recent years, the world price of the material had declined considerably and Canada had recently sold uranium to Japan at 35s./lb. After the termination of these contracts, therefore, the Union would also be adversely affected by the drop in price of the mineral which, at the current rate of production of about 6,200 tons of oxide/annum, is earning the country over £50m./annum. Dr. Schumann added, however, that a favourable change in the world demand for uranium was generally expected by 1970, with consequent advantages for South Africa.

Space Laboratory

The Westinghouse Electric Corporation is establishing a new "Astroelectronics Laboratory" in California's Conejo Valley, 40 miles north-west of the city of Los Angeles. The new laboratory will work closely with the military services and the defence industry located on the west coast of the United States, particularly in the development of advanced electronic techniques for application in the missile and space areas. These include molecular electronics semi-conductors and thermo-electrics and sensing tubes.

Effluent Convention

The paper, "Disposal of Radioactive Effluent—an increasing problem" by P. A. L. Northcott, BSc, PhD, to be presented to the first Effluent and Water Treatment Convention in October at the Seymour Hall, London, will include a report on the effects of the Radioactive Substances Act 1960 recently passed in Parliament. The Act provides for permanent control over discharges from the major nuclear establishments; for other users of radioactive materials to be registered and to require authorization from the Minister for the disposal or accumulation of radioactive waste; and for the setting up of a national service for the disposal of radioactive wastes which cannot be safely disposed of locally.

More than 75 experts from 19 different countries attended the Symposium on the Effects of Ionizing Radiation on Seeds and Their Significance for Crop Improvement jointly arranged by the International Atomic Energy Agency (IAEA) and the Food and Agriculture Organization of the United Nations (FAO), held at Karlsruhe, Germany, recently. Over 50 papers dealing with the effects of various radiations on seeds, seedlings and plant material, post-irradiation effects, theoretical explanations and the mechanism of action of environmental factors during and after irradiation, as well as the application of these effects for the improvement of crops were presented.

N-Naval Officers in Training

Officers from the Royal Naval College, Greenwich, at the controls of JASON, the research and training reactor of the Hawker Siddeley Nuclear Power Co., Ltd. They were on a two day course organized by the College and company to give the students practical operating experience with a critical facility and an opportunity to carry out experimental work with a reasonable neutron source. The students were in the third and final term of their one-year Advanced Nuclear Course arranged by the Nuclear Science and Technology Department of the College. Most of them have since joined the Admiralty nuclear projects team at Bath. One officer is in the U.S.A. for training in one of the USN nuclear submarines and others are teaching in the nuclear field. JASON is available to any organization wishing to use it for training purposes. Two categories of courses are available. One, the basic course, works out at about £5 5s. a day/student. The other, advanced course, costs £15 15s. a day/student. Further details are available from Mr. D. H. Baines, technical sales manager, Hawker Siddeley Nuclear Power Co., Ltd., Sutton Lane, Langley, Nr. Slough, Bucks.

Contracts Awarded

Auxiliary burst slug detection equipment designed and produced by Plessey Nucleonics Ltd., has been chosen by the UKAEA for the advanced gas-cooled reactor at Windscale. The installation, which will be incorporated in the reactor's loop facilities, comprises a specially designed precipitator and associated counting, recording and electronic equipment. The company is also in the process of developing portable and installed detectors for the test loops and refuelling machine.

* * *

The Solartron Electronic Group Ltd., Farnborough, Hants., were recently awarded a contract to provide the instrumentation and control apparatus for the Intermediate Current Stability Experiment (ISCE) to be situated in the new laboratory which the Atomic Energy Authority are establishing at Culham, near Oxford. Solartron will be responsible, among other things, for the design and manufacture of the control room apparatus, which will include current and voltage measuring and recording equipment of a very high order of accuracy, and speed of responses.

* * *

Alco Products, Inc., have received a contract from the U.S. Army Engineer Centre at Fort Belvoir, Virginia, to study the technical aspects of operating, testing and maintaining army field nuclear power plants. The contract for such service, which will take five months, amounts to $168,000. Six nuclear engineers, four technicians and two administrative personnel from Alco are stationed at Fort Belvoir until November 30th and during their stay will be responsible for compiling and furnishing written engineered solutions to problems peculiar to the use of field-type nuclear power plants.

* * *

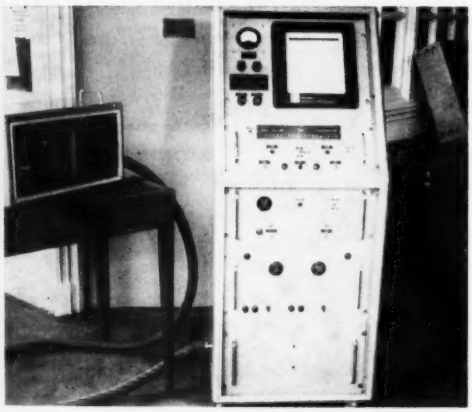
W. H. Allen Sons & Co., Ltd., have received an order for six Allen-Stoeckicht epicyclic gear units for motor driven horizontal circulating-water pumps for installation in the CEGB nuclear power station at Trawsfynydd. These units, ordered by Drysdale & Co., Ltd., of Glasgow, are designed to transmit 1,150 h.p. continuously each and reduce the motor speed of 960 rev/min to the pump speed of 180 rev/min.

Equipment and Materials

Items published in this monthly feature are compiled from manufacturers' current literature. Readers requiring further information should use the form at bottom of the page. Manufacturers are invited to send literature or details of their products for inclusion in this feature.

Beryllium Monitor

The "4W" beryllium monitor manufactured and marketed by Winston Electronics, Ltd., is said to be the most completely automatic, accurate and rapid instrument of its type yet made. Designed and developed by members of the Atomic Energy Authority's research outstation staff at Woolwich, it visually records every 60 sec the amount of beryllium in a fresh sample of the atmosphere in which the instrument is present. It is essential to the health of persons employed in workshops and laboratories using beryllium, its ores and alloys, that the beryllium concentration should not exceed two millionths of a gram/cu.m. Also, it is essential that sudden or unexpected increases in beryllium concentration should be quickly indicated, as

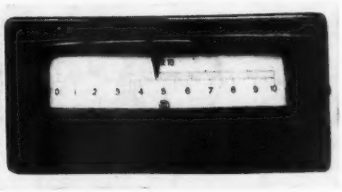


The Winston "4W" beryllium monitor

with this new instrument, and, automatically, some kind of warning given. The "4W" monitor gives quantitative results over the range of 1 to 75 millionths of a gram/cu.m, irrespective of the particle size or chemical composition of the beryllium atmospheric dust. The air to be sampled is drawn through a specially designed chamber in which any beryllium present is optically excited as it passes through a triggered a.c. arc. The chamber has been carefully designed aerodynamically to eliminate pockets of beryllium concentration. The triggered a.c. arc has a long time constant and a wide plasma cross-section which result in very efficient excitation of particulate beryllium metal and its intermediates. The ultra-violet radiations from the excited beryllium are then resolved into their components by means of a spectrograph, which is specially designed to have a high dispersive power. The intensity of the beryllium doublet at 3,130A°, which is proportional to the concentration of beryllium present in the air sample, is measured photoelectrically and then the ratio of the intensity of this doublet to the intensity of the adjacent background is recorded on a chart. The arc chamber is designed so that the air sample is directed into the centre of the arc and the electrodes are placed so that the air flow is along the length of the arc plasma, ensuring that airborne dust remains in the excitation zone for the maximum time. The automatic calibration is achieved by the use of a simple condensed spark discharge between a beryllium-copper electrode and a copper counter electrode producing an aerosol containing a uniform concentration of beryllium at a constant rate, the air for this being drawn through special filters. The monitor is fully automatic and it operates on a predetermined cycle in which it is first calibrated and then records a series of results, at 1 min intervals. **(SEP 1)**

Self-Balancing Indicator

The Bailey electronic self-balancing 8 in. edgewise indicator is designed to operate with input signals from thermocouples, resistance elements, or telecoils. When the instrument is used in conjunction with a Bailey switchbox, multipoint indication can be obtained. Depending upon the type of measuring element used, a Wheatstone bridge, inductance bridge or potentiometer circuit forms the input to the servo system. The measuring element is part of the bridge network. When a change in the quantity being measured occurs, the effect on the element disturbs the bridge balance. The out-of-balance signal, after detection and amplification, is used to drive a two-phase servo motor which restores balance to the bridge network. The indicator pointer is fixed directly to the slide-wire shaft, thus indicating the angular position of the shaft, and hence the state of the variable quantity, without lost motion. The servo motor, its gearbox, damping device and slide-wire are



Bailey's electronic self-balancing 8 in. edgewise indicator

completely sealed in a die-cast case which is filled with constant viscosity silicone oil. This ensures critical damping of the motor and very low wear rates on the moving parts at all temperatures. Electrical connections to the motor and slide-wire are made via ceramic feed-through insulators. The servo amplifier is a four-stage high gain unit, so designed that all thermionic valves, and the amplifier gain control, are readily accessible. Electrical connections to the remainder of the servo system are made by plugs and sockets to allow easy maintenance. When the instrument is used in conjunction with thermocouples, a transistorized d.c./a.c. converter and a neon-stabilized reference voltage are used. **(SEP 2)**

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Please send further details of the following items in the EQUIPMENT & MATERIALS *feature for September, 1960*

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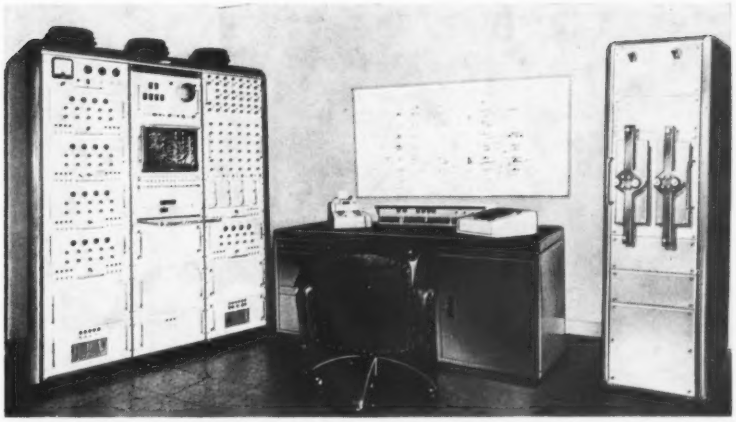
Address .....

Computer System

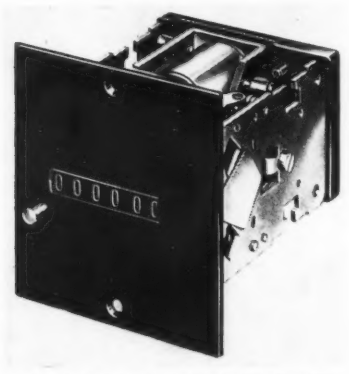
A new electronic computing and data handling system has been developed by Redifon, Ltd., of Crawley, Sussex. Called RADIC (Redifon Analogue-Digital Computing System), it has been designed for general purpose use. It is claimed to be the first of its kind in the world specifically developed to effectively integrate the stability, convenient input-output equipment and extensive storage facilities of the digital machine with the speed of operation, ease of programming and low cost of the analogue. Cost of the RADIC system will range from about £10,000 but it can be easily expanded if required into a large computing system costing up to £150,000. This brings the system within the reach of even the smallest company or organization requiring a flexible computing system for carrying out complex calculations, simulation and data reduction. A major field of application will be the analysis and computation necessary for designing automatic process control equipments for various complex industrial processes such as may be found in the oil, steel, auto, aircraft, chemical and nuclear industries. In particular, the new system is considered the first practical tool for the analysis and design of heat exchangers and chemical reactors which defy normal mathematical treatment and to which only poor approximations are available. This may become one of the principal applications for this equipment. Other particular uses where conventional computer techniques are not really adequate will be where quick, almost instantaneous solutions are required for coping with rapid changes of production schedules, minimization of transportation time and costs and automatically sorting out significant features from the large amount of statistical data turned out by electronic data processing systems. **(SEP 3)**



Typical medium sized installation of the new Redifon analogue-digital computer system

Counter Range

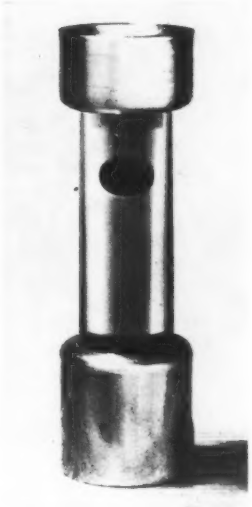
A versatile range of counters has recently been introduced by the Telephone Manufacturing Co., Ltd. Known as TMC Elmeg Counters, they are available in printout and readout form, with fast operating speeds of up to 40 impulses/sec. Operating on up to 240v, with uni-directional or bi-directional motions, they can be reset to zero by electrical, mechanical or electro-mechanical methods. Some have auxiliary contacts which operate on each revolution of a numbered wheel. Offering utmost reliability, the range includes counters for flush panel and surface mounting. No special servicing is required and certain of the range are extremely compact. Generally, the counters can be used in conjunction with proximity switches or photocell equipment on production flow lines; in factory statistical equipment; in factory process control; and in computers and office accounting machines. **(SEP 4)**



One of the new TMX Elmeg Counters

New Flow Indicator

Since the introduction of additive-oils, the difficulty of indicating small flows has become increasingly apparent. In some cases, the characteristics of the oil are such that the conventional type of flow indicator will not work at all. In others, reasonable results can only be obtained if the glasses are removed at frequent intervals for cleaning and maintenance. It is, of course, possible to obtain accurate measurements by using special flow meters. These are virtually laboratory instruments and are inevitably extremely expensive. The Muntz direct flow indicator, which operates on the ball and tube principle, has been specially developed to overcome these difficulties, and it is confidently offered as a complete solution to the problems of flow indication associated with the use of additive oils. The indicator consists of a ball in a transparent tube with a tapered bore, so arranged that as the flow increases the ball rises in the tube. An indication of the actual flow rate is therefore obtained. This neat, compact and easy-to-read device is at present being manufactured in three different forms. In each case the operating principle is the same, but different layouts are used for ease of installation. One is a standard single indicator, suitable for inclusion in any oil line and another a replacement indicator, which can be substituted directly for other types of sight glasses. The third is a multi-point panel, which is an extremely compact arrangement designed for use where a large number of indicators is required. All the units are grouped together and it is thus possible to check the various flows almost at a glance. These flow indicators contain no special liquids, which means that contamination of the oil is impossible and fitting presents no difficulty. All components are manufactured to close tolerances and are therefore fully interchangeable. The various arrangements of direct flow indicator are designed to operate at pressures up to 1,000 lb/sq.in. **(SEP 5)**

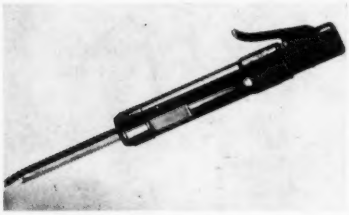


The Muntz direct flow indicator

Versatile Tool

A new chipping and scaling hammer, known as the CP-455-L, has been introduced by the Consolidated Pneumatic Tool Co., Ltd. Whilst the new hammer has been designed to meet the need for a lightweight powerful weld flux chipping tool, it is nevertheless widely suitable for chipping stone, metal, concrete and for carving wood. Clearance of chippings from the workpiece is catered for in this new tool by a jet of high velocity air which may be directed downwards, thus enabling the chisel point to be kept clear. This new chipper uses a piston of $^{15}/_{16}$ in. bore and 1 in. stroke which gives 4,200 blows/min at a pressure of 90 lb/sq.in. A particular feature is the use which has been made of a new type

"pulley valve" which gives the same smooth throttling action as the somewhat heavier spool valve employed on larger hammers, thus enabling accurate control to be made of the speed and power of the hammer, this being by a lever type throttle. The pulley valve employed has a larger

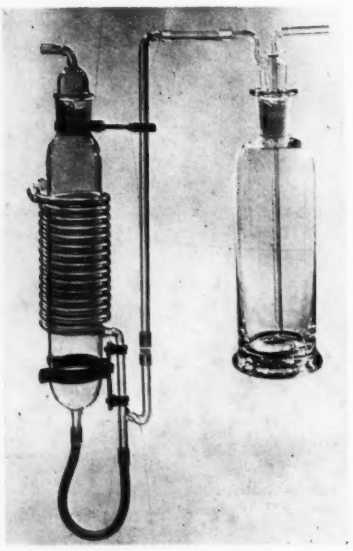


The CP 455 L Chipping hammer

diameter and shorter length than the spool valve, the resultant increase in working area of the valve enabling it to operate without loss of power when the valve clearance increases due to wear. The standard chisel supplied with the tool is an angle scaling chisel, although a narrow blade chisel is available if required. The chisels are held in the hammer by a positive retaining device and cannot rotate, change-over being effected by a simple quick release retaining clip. The nett weight of the tool is 4½ lb and the overall length is 10½ in. The size of the air inlet thread is ¼ in. **(SEP 6)**

Free of Oxygen

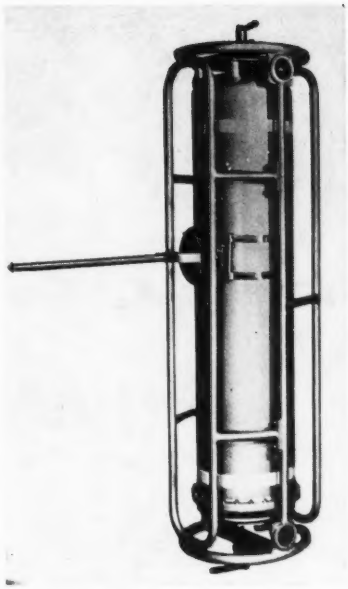
The "Nilox" gas purification system introduced by Southern Instruments, Ltd., enables the laboratory worker to obtain on the turn of a tap a continuous stream of hydrogen, nitrogen, argon, etc., completely freed of the oxygen normally contaminating these gases as supplied in cylinders. Ordinary commercial nitrogen can be purified to a degree much superior to high purity commercial nitrogen and will reduce an oxygen content of 2,000 p.p.m. down to 0.2 p.p.m. The apparatus consists of a prepurifier containing an organic reagent which absorbs the major part of the oxygen. This reagent is then regenerated in contact with a bed of lead wool. The gas then passes to a scrubber which finishes off the purification. This scrubber is designed for highly efficient gas-liquid exchanges. The primary absorbent is a chromium salt which is oxidized, but reduced back by contact with amalgamated zinc. The gas stream may flow at any rate up to 20 litres/hr and the reagents need only be renewed at long intervals. **(SEP 7)**



Nilox gas purification apparatus

New X-Ray Unit

A new lightweight, portable industrial X-ray unit of 300 kV capacity, known as the Baltospot G300D has been introduced by Pantak, Ltd., for examination of mild steel of up to 3 in. thickness. Both insulation and cooling of the X-ray tube in this unit is effected by a chemically and physiologically inert and non-inflammable gas. The use of this medium results in a lightweight tank head construction and achieves a high power/weight ratio, the weight being 142 lb and the capacity being 300 kV. The unit can be supplied with either a conventional 40° solid angle beam insert tube with a fine focus, size 3.0 mm or a 360° circumferential radiation insert tube. Cooling of the anode is achieved in either case by forced circulation of the insulating gas by means of an internal blower. The tank head which is cylindrical in shape is pressurized and is fitted with a pressure gauge so that the insulating gas may be checked at any time. A cradle is supplied in which are incorporated anti-shock mountings. The tube is protected against excessive temperature by a thermo switch mounted in the tank head. A further



The Baltospot 300 kV X-ray unit

device in the control unit simulates the thermal capacity of the anode and gives the operator a visual indication of overheating. A particular advantage is that a series of exposures can be planned without risk of overheating the tube. The maximum dimensions are 40 in. long × 9 in. diameter. When fitted with the protective cradle the weight is increased from 142 lb to 171 lb. The control unit is of the carrying case type, the maximum dimensions being 18 in. long × 14 in. wide × 8 in. deep. The weight is 60 lb. **(SEP 8)**

BOOK REVIEW

Atomic Radiation and Polymers, by A. Charlesby. Published by Pergamon Press Ltd. Size 6 in. × 8¾ in. × 556 pp + xiii. Price 110*s.* 0*d.*

The irradiation of polymers is a subject which forms a part of two rapidly developing fields—radiation chemistry and polymer science. Few people can have expert knowledge of both fields, so that the appearance of this book is of more than usual interest. Professor Charlesby begins with six chapters introducing the radiation side, followed by two chapters on polymers. The main part of the book consists of an advanced discussion of the results of irradiating polymers and vinyl monomers. Concluding chapters discuss the mechanism of the reactions observed and certain special topics such as the use of polymers in reactors. Natural polymers of primarily biological interest, such as proteins or nucleic acids, are not discussed. The inclusion of vinyl compounds and the exclusion of natural polymers are the main differences from the only other book I know of on the subject. (Surprisingly it is claimed on the dust jacket that this is the first book to be published in the field, although another has been available since 1958). This book can be highly recommended to those wanting a substantial treatise on the subject. Professor Charlesby writes with unquestionable authority, being one of the originators of his subject, and a constant contributor to it. His style is straightforward and clear. The number of misprints and other minor errors is not unreasonable, although one surprising error is that the photograph on page 340 appears to be the negative! The minor errors and inconsistencies could have been eliminated by further checking, although this would have delayed publication by several weeks. This is an important point because the main adverse criticism of the book must be the delay in publication. Some 1958 work is discussed, although there is no reference to the 1958 Geneva Conference on the Peaceful Uses of Atomic Energy, at which several papers on polymers were presented. Some chapters even discuss work published in 1959, usually by the author himself and his collaborators. But much of the book covers the literature only up to 1957. Remembering that a newspaper can contain news of events occurring only an hour or two earlier, is it not possible for book publishers to devise some method of publishing more quickly?

A. J. SWALLOW,
Imperial College of Science and Technology.

ISOTOPE WORLD

A Supplement devoted to the Subject of Radioisotopes

OVER 300 ENQUIRIES IN SIX WEEKS

THREE hundred and forty-four enquiries were received at the UKAEA's Isotope Information Bureau in London during the first six weeks since its opening in June. About one-sixth of these were of a specific nature and came from industrial organizations with particular problems to solve. The remainder were very general and mainly of the type " What is a radioisotope?" and " How are isotopes made?"

Of the 50 specific enquiries the largest proportion were about the use of isotopes for thickness measurements and for use as tracers. One organization wanted to know, for instance, how they could apply isotopes to measuring the gum on cigarette papers and another required information on their application in measuring wear of coal crushing equipment and of refractory linings. Another enquiry was about their use in studying the silting up of water intakes at power stations.

The sterilization of hospital equipment and the application of radioisotopes in agriculture have also been the subject of enquiries.

Most enquiries were apparently made by personal callers, representatives of overseas firms being amongst them. Others were made in letters and over the telephone.

General enquiries can be answered usually on the spot. In the case of enquiries which cannot be so answered, however, Bureau staff will put enquirers in touch with the appropriate departments of the Authority, such as the Radiochemical Centre and the Wantage Radiation Laboratory.

The Bureau, which is under the general supervision of Mr. A. J. Wood, is fitted out with a library of reference books and a non-technical exhibition demonstrating some of the various applications of isotopes in industry and illustrating how they are packed and distributed. There is also a compact projector for the screening of suitable films.

Address of the Bureau is Isotope Information Bureau, UKAEA, 11, Charles II Street, London, S.W.1. Telephone number is Whitehall 6262.

Part of the Isotope Information Bureau situated on the ground floor of the U.K. Atomic Energy Authority headquarters at Charles II Street, London. Exhibition panels illustrate various applications of radioisotopes in industry. In charge of the Bureau is Mr. A. J. Wood, seen here answering an enquiry from Mr. Waldow, of Kiev, Germany

Automatic Beta Counting

PRECISE automatic measurement of beta emitting samples containing low level amounts of C14, P32, S35, Sr90, etc., is possible with the new C115 Sample Changer introduced by the Nuclear-Chicago Corporation, of Illinois. The low background of the instrument, of two counts/min, makes it possible to analyse samples with counting rates as low as 2 to 3 counts/min. In routine sample measurements counting time can be significantly reduced while the amount of radioactive reagent required can be substantially cut. High sensitivity of the system is achieved through the use of a new gas flow sample detector, while low background is accomplished by the use of carefully selected materials in its construction, generous shielding and a unique " guard " detector which acts as a cosmic ray shield for the gas flow sample detector. The Changer is used in conjunction with a scaler, printing timer, Q-gas and gas regulator. The changer will accept as many as 35 samples which can be prepared in the special low-background copper pans supplied with the instrument. The chamber positions each sample in sequence under the gas flow detector and automatically activates the scaler for counting. The time required for each sample to reach a selected preset count is recorded by the printing timer, together with the sample identification number. The entire system can be left unattended overnight or over weekends.

Activity Simulated for Training

TRACERLAB Inc., are to supply the U.S. Navy Training Centre with a non-radioactive system for training personnel in radioactivity detection and de-contamination procedures. A " phosphor " compound known as POPPOP will be used to simulate the radioactivity and an instrument incorporating an ultra-violet light source, to excite the " phosphor," and a photomultiplier tube to detect the light rays emitted by the " phosphor," will be used to simulate a Geiger counter. In operation this instrument will produce the characteristic click of a Geiger counter and will give indications of " radioactive strength " on a meter.

Remote Weather Station

THE Martin Co., of Baltimore, have received a $150,000 contract from the U.S. Atomic Energy Commission to build an automatic electronic device for recording weather conditions in remote locations. Energy will be supplied by a 5w generator which will convert heat from pellets containing radioactive strontium-90 in the form of strontium titanate. This compound remains stable even beyond its melting point of 3,000° F. and has an exceedingly low rate of solubility in water. The pellets will be encased in several layers of an alloy called Hastelloy-C. In the first telemetry unit radiation shielding will be provided by means of more than half a ton of lead.

Copenhagen Conference

OVER 154 papers are to be read at the Conference on the Use of Radioisotopes in the Physical Sciences and Industry to be held in Copenhagen, September 6th to 17th. They have been prepared by scientists from 18 countries and include 31 from the United Kingdom. The conference has been arranged by the International Atomic Energy Agency in co-operation with UNESCO.

To Larger Office

TRACERLAB (Holland) NV, European subsidiary of Tracerlab Inc., the American radiochemical manufacturing firm, has moved to larger offices. They are at 119, Singel, Amsterdam. According to Tracerlab's vice-president for marketing, Mr. H. S. Myers, the move has been necessitated by an increase in European sales of Tracerlab nuclear electronic equipment, an increase made despite competition from European firms.

Isotope Power for Space Rockets

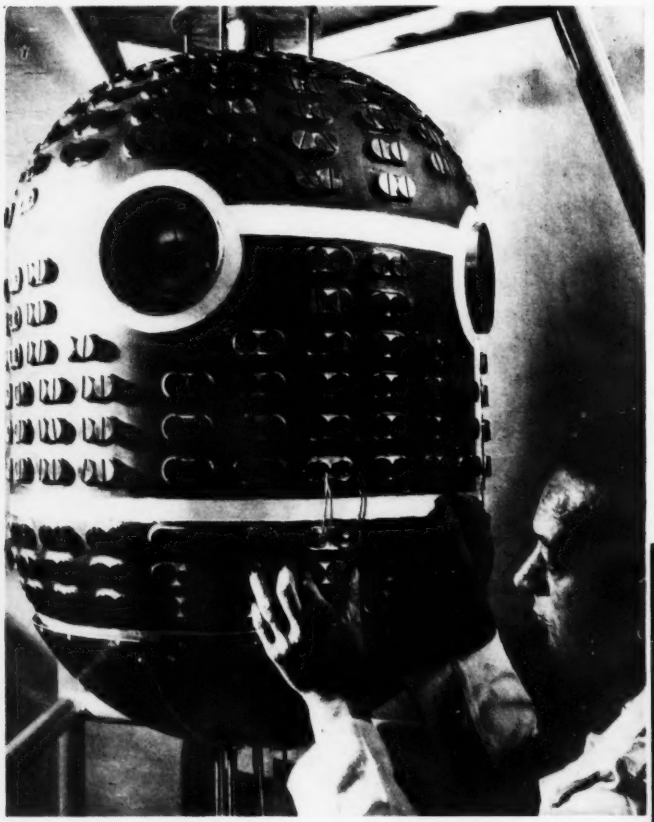
TESTS have started on SNAP 1-A, the cerium-144 fuelled power generator developed by the Martin Company, of Baltimore, for powering instruments, etc., in advanced satellites and space probes. Heat from the radioactive isotope is converted into electricity in the same way as it is in SNAP-3, the grapefruit-sized device which was first demonstrated publicly by President Eisenhower early last year.

SNAP 1-A (the letters stand for System for Nuclear Auxiliary Power) is roughly egg-shaped, 34 in. long and 24 in in diameter. Most of its dull metal surface is dotted with screw-headed caps marking the location of 277 thermocouples. Total weight of the generator is 175 lb. Power output is 125w at 28v.

The system promises more power than any energy unit launched into space so far either by America or the Soviet Union. Some systems have combined solar cells with chemical batteries to build up appropriate wattages periodically, but these cannot operate continuously at high power.

Martin Company engineers point out that SNAP 1-A, unlike solar cells, would not be affected by the impact of micrometeorites in space. Operating independent of the sun, the nuclear unit would have the additional advantage of being able to produce power while in the shadow of the earth. The absence of moving parts in the conversion system reduces the chances of malfunction.

The fuel capsule for SNAP 1-A, which will not be inserted until electrical and environmental tests of the rest of the system are complete, will be located at the centre of the generator, supported by light metal tubing. The Ce144 will be contained within tightly-sealed pellets.



SNAP 1-A, the isotope generator developed by Martin, ready for testing

Artist's impression of Discovery-type satellite mounted with two SNAP 1-A units for powering instruments, etc.

While the inner ends of the thermoelectric elements are heated by the decaying cerium, the outside ends always remain somewhat cooler. The difference in temperature that results produces a small electric current. Tests being conducted now use an electrical heater to simulate the fuel.

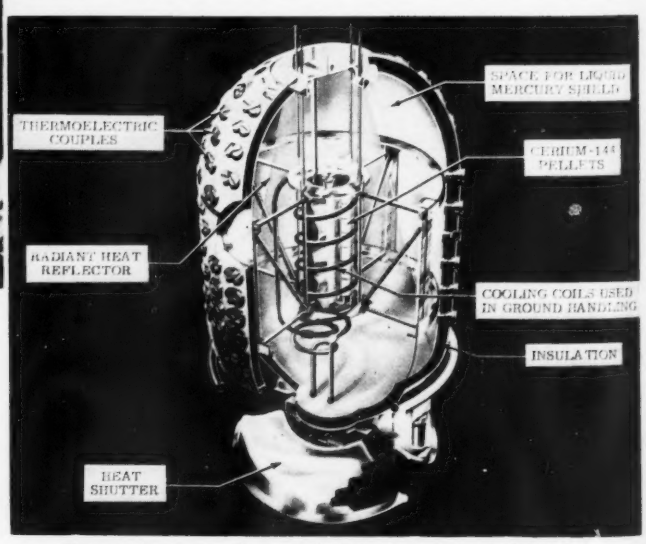
Ce144 is a normal by-product of the fission process in all nuclear reactors. The material which ultimately will power SNAP 1-A is being separated from other fission products at the Oak Ridge National Laboratory of the U.S. Atomic Energy Commission and will be supplied to Martin in sealed form early next year for use in the ground test unit.

As the radioisotope decays, the amount of heat it produces will gradually decrease. For this reason, SNAP 1-A has been built with a temperature-sensitive shutter, which will let some of the heat leak out at the beginning of operation but will gradually clamp shut. Thus the electrical output will remain constant at 125w for a full year and then will taper off.

A solar cell system with the same constant output might be comparable to SNAP 1-A in weight, but would be much bulkier unless a complex mechanical device were used to keep the cells pointed toward the sun. Unoriented cells would have to cover an area of more than 100 sq.ft.

Extensive and conclusive tests have been carried out under contract to the AEC to assure that the radioisotope fuel of SNAP 1-A would not be released if a satellite-carrying rocket exploded on the launch pad or failed to reach orbital velocity. Once in orbit, the fuel capsule is designed to burn up completely upon re-entry into the atmosphere.

During ground-handling operations before launch, the hollow interior of SNAP 1-A can be filled with liquid mercury, which acts as a shield for its radiation. This could be drained, moments before lift-off, to reduce the weight of the payload.



Cutaway drawing to show principal design features of SNAP 1-A

Radioisotope Production in Power Reactors

FEASIBILITY AND ECONOMIC STUDY

BY producing radioisotopes in power reactors their cost can be greatly reduced. In America it is estimated that cobalt-60 irradiated in the Dresden boiling water reactor would cost $0.379 per curie, as compared with the $2 to $5 currently charged in that country. The price of carbon-14, it is estimated, could be reduced from $13,341 to $2,280 per curie.

These estimates are contained in a report of a study undertaken by Booze-Allen Applied Research, Inc., of Illinois, for the U.S. Atomic Energy Commission into the feasibility and economics of radioisotope production in power reactors. The study, which took seven months to complete, covered the production of six radioisotopes in various parts of three different types of reactor. The isotopes were cobalt-60, carbon-14, tritium, phosphorus-32, sodium-24, and potassium-42. The reactor types were the boiling water at Dresden, the pressurized water at Shippingport, and the organic moderated at Piqua—all three designed primarily for power production.

Objects of Study

One objective of the study was to find out whether or not worthwhile isotope production would be possible without significantly interfering with the design or output of the reactors. Another objective was to determine whether the specific and the total activities of the various isotopes produced, as well as the cost of production, would be such as to be economically attractive to reactor operators or other private industries interested in isotope production.

More than Enough

In achieving the first objective it was found that by making use only of the very best target areas within the reactors, and assuming very conservative target loadings, all three reactors had the capacity for producing very significant amounts (in comparison to the present market) of tritium, C14 and relatively high specific activity Co60. At the same time it was found that none of the locations within the reactor's cores considered (with the exception of the organic moderator in the Piqua plant) would be practical for the production of the relatively short-lived isotopes P-32, Na24 and K42.

To produce these particular isotopes, rabbit tubes placed at the fringe of the cores would have to be used, and then, except in the case of P32 production at Shippingport, quantities many times greater than those currently in demand could be produced.

Two specific cases of isotope production were singled out for economic analysis. In the first the U.S. demand for all six isotopes during 1959 was estimated (the study was started about half-way through 1959 and these estimates were based on USAEC sales of isotopes during the first six months of that year). The simultaneous production of all six isotopes in each of the reactors was then considered and the results related to the estimated 1959 sales.

In the second case consideration was given to the maximum individual production of the long-lived isotopes and P32 in each reactor. Maximum production of Na24 and K42 was not considered because the production capacity of all these reactors is tremendously in excess of any reasonably assumed market.

The estimated new prices based on these two analyses are contained in Tables III and IV. From these tables it would appear that the production of the long-lived isotopes, Co60, H3 and C14, either in combination or individually, appears to be more economically attractive than the production of the short-lived isotopes. The short-lived isotopes suffer in comparison because the pricing used was strongly influenced by packaging costs and there are many more shipments made of these short-lived isotopes than of the long-lived ones.

Prices for combined production of all six isotopes in the Piqua OMR were not estimated because the fraction of the current market of the long-lived isotopes that could be produced is low. The costs of producing 40 per cent. of the market for the long-lived isotopes and all of the market for the others, however, were estimated to be $308,530 per year, the value of this quantity of isotopes at current prices being about $652,000.

Best Places in Dresden

In respect of the Dresden reactor it was concluded that the best places for producing the long-lived isotopes were empty fuel spaces. This was particularly true for Co60, as a premium is placed on high specific activity for this isotope.

Making use of only the best locations for the placement of all target materials, including rabbit tubes sited in the core fringe, the Dresden reactor would be capable of producing more than the 1959 market estimate for all six isotopes. If only fuel spaces were used then the reactor would be capable of producing three times the 1959 estimate for Co60, seven times the market for tritium, and about 10 times the

Table I.—Sale of Isotopes covered by Survey during 1959—U.S.A.

Isotope	*Half-life*	*Sales in curies 1959*	*AEC Selling price/curie* $	*Revenue 1959* $
Co60	5.28 years	210,982	2 to 5	691,008
Tritium	12.26 years	50,063	2	106,035
C14	5,600 years	12.7	13,000	286,090
P32	14.3 days	183.3	1,000–3,000	193,036
K42	12.4 hr	11.2	2,000	22,438
Na24	15.0 hr	4.2	7,000	10,872

Table II.—Comparison of Actual Sales of Isotopes in 1959 with Estimated Sales made for purpose of Study

Isotope	*Estimated 1959 Demand*	*Actual Sales in 1959*
Co60	183,000	210,982
Tritium ..	40,000	50,063
C14	14.4	12.7
P32	166.0	183.3
Na24	5.0	4.2
K42	13.0	11.2

Table III.—Estimated New Prices for Combined Production

Isotope	*AEC Price/Curie* $	*New Price/Curie Dresden* $	*Shippingport* $
Co60	3.105	0.379	0.65
H3	2.192	1.095	1.84
C14	13,341	4,000	4,730
P32	1,290	1,020	1,435
K42	2,800	4,700	4,780
Na24	8,600	10,440	10,620

Table IV.—Estimated New Prices for Individual Production

Isotope	*Yearly production in curies*	*New estimated price/curie* $	*Yearly profit at 15 per cent. sales* $
Isotopes produced in Dresden BWR			
Co60	581,500	0.47	41,060
H3	335,620	1.38	69,580
C14	141.6	2,820	59,780
P32	408	1,530	93,630
Isotopes produced in OMR—Piqua			
Co60	159,030	0.80	19,030
H3	47,790	2.26	16,330
C14	30.13	4,970	22,410
P32	6,552	557	546,650
Isotopes produced in PWR—Shippingport			
Co60	243,520	0.71	25,870
H3	166,840	1.36	33,900
C14	73.3	3,000	32,610
P32	81.5	2,390	29,200

market for C14. If four rabbit tubes were used about 2½ times the 1959 estimate for P32 could be produced.

In respect of the Piqua reactor it was found that if all six isotopes were produced simultaneously, quantities of the short-lived isotopes well in excess of the 1959 estimates could be produced (in two rabbit tubes) and about 40 per cent. of the 1959 estimates for each of the long-lived isotopes (in interstitial core locations).

Piqua Possibilities

If the long-lived isotopes were produced individually in the Piqua reactor, 87 per cent. of the 1959 estimates for Co60, 209 per cent. of the market for C14, and 117 per cent. of the 1959 estimates for tritium would be produced. The best locations for producing the long-lived isotopes were found to be the interstitial core positions around the fuel elements and control rods.

In general rabbit tubes would provide the only practical method of producing short-lived isotopes, though very significant quantities of P32 could be produced in the Piqua reactor by adding small quantities of sulphur to the organic moderator-coolant. Booze-Allen point out that this method of production might have application to isotopes not considered in their study.

It was found also that large quantities of C14 could be produced by using a nitrogen containing material as the moderator coolant. The isotope produced would be of very low specific activity.

Studies into the use of the Shippingport pressurized water reactor revealed that three long-lived isotopes could be produced in three reactor locations—inside control rods, in holes in seed cluster spacers and in grid spaces at the edge of the core.

Method of Approach

To reach their objectives the study group, headed by Dr. George Rotariu, first of all determined the specific activities of the six isotopes as a function of neutron flux and irradiation time. They then selected what they considered the best target material for the production of the isotopes and determined the sites in or around the three reactors that could possibly be used for target locations.

Each selected site was then considered with regard to the types of target containing tubes that could be used and the total quantity of target materials that could be installed was estimated. On the basis of effective neutron fluxes existing in the selected sites calculations were made as to the specific activities and total activities of each isotope that could be produced in reasonable irradiation time. Some examples of the results obtained from these calculations are contained in Table V.

Those sites which were determined to be impractical from the point of view of isotope production were then eliminated from further consideration and effort was concentrated on determining the maximum production of each isotope in the best target locations and the combined production of all isotopes in each reactor. The economics of both individual and combined production were then analysed and the new prices based on a 15 per cent. profit margin established.

Calculations as to the effect on the price of the radioisotopes of increased fuel enrichments necessary were also made.

The report of the study—AECU-4355 UC-23 Isotopes—Industrial Technology—is available from the Office of Technical Services, Department of Commerce, Washington 25, D.C., price $2.45.

CHOICE OF ISOTOPES IN STUDY

The choice of isotopes considered in the study was governed by various factors. Cobalt-60 was selected because of its widespread use in radiography and radiotherapy, which makes its yearly volume of sales in total curies the largest of any isotope, and because of its potential use in very large-scale irradiation sources. Carbon-14, although its sales volume is small, is of importance in research and at the same time its unit cost is high. A market for it is assured and a reduction in its cost would be of importance. It must be realized, however, that the cost of C14 labelled compounds, because of the labour involved in their preparation and distribution, might not be greatly affected by a price reduction for the isotope. Tritium, important industrially and in research, was chosen because its sales volume is relatively large and seems to be significantly increasing. The yearly revenue from the sale of phosphorus-32, which is important mainly in medical applications, is large because the unit cost is high although curie volume is relatively low. A cost reduction would be important. Sodium-24 and potassium-42, useful in medical research, but not in great demand, were selected mainly for the purpose of investigating the problems of short-lived isotope production.

Table V.—Some of the Activities Produced in Certain Areas of the Reactors

Isotope	*Specific Activity*	*Total Activity*	*Total Mass of Target Material*	*Effective Neutron Flux*
Isotope Production in Fuel Spaces (350 of them) in Dresden BWR—Irradiation Time: 1 year				
Co60	18.4 c/gm	581,500c	31.60 kg Co59	2.63×10^{13}
H3	1,500 c/gm	275,600c	9.10 kg LiF	2.05×10^{13}
C14	5.23×10^{-3} c/gm	141c	53.15 kg Be_3N_2	3.15×10^{13}
Isotope Production in Interstitial Spaces (114 spaces) in Piqua OMR—Irradiation Time: 1 year				
Co60	12.2 c/gm	102,200c	8.37 kg Co59	1.57×10^{13}
H3	900 c/gm	30,400c	1.67 kg LiF	1.37×10^{13}
C14	3.48×10^{-3} c/gm	19.5c	11.00 kg Be_3N_2	2.1×10^{13}
Isotope Production in Grid Spaces (21 of them) in Shippingport PWR—Irradiation Time: 1 year				
Co60	29 c/gm	133,000c	4.58 kg Co59	3.75×10^{13}
H3	2,100 c/gm Li6	137,000c	3.24 kg LiF	3.25×10^{13}
C14	8.3×10^{-3} c/gm	60.1c	14.2 kg Be_3N_2	5×10^{13}

Isotopes in the Petroleum Industry

by Vincent P. Guinn

THE petroleum industry was one of the first to make effective use of radioisotopes in research and in processing operations, and it remains to-day as a leader in this field. Its utilization of radioisotopes ranges from small-scale laboratory studies of chemical reaction mechanisms to pilot plant tracer studies, to full refinery-scale mixing and flow studies in catalytic cracking units. In this article some of the more recent developments in the use of radioisotopes in research, development and refinery operations in the petroleum industry are reviewed. Applications in the area of exploration for, and production of, petroleum, although similarly extensive, are not included.

The refining of crude petroleum into a variety of high quality finished products, such as ethylene and propylene (for the chemical industry), propane, butane, high octane gasoline, jet fuel, diesel fuel, lubricating oils, greases, paraffin, and asphalt, involves a great variety of physical and chemical processes. Physical processes employed include distillation, extraction, crystallization, and adsorption. Chemical processes employed include cracking, polymerization, alkylation, hydrogenation, dehydrogenation, isomerization, and cyclization. All of these operations, especially when carried out in pilot plant and refinery scale, pose numerous problems which can be, and are, attacked effectively by radioisotope techniques.

In refinery operations, feed stock to be fed to a catalytic cracking unit must first be vacuum-distilled to free it from various high boiling metallo-organic compounds present which are deleterious to the cracking catalyst—even when present in the feed at parts-per-million levels. A difficulty often encountered in vacuum distillation is that of entrainment of spray from the bottoms in the overhead distillate, which defeats the purpose of the distillation. Such entrainment is difficult to measure quantitatively unless a radiotracer method is employed. Such a method has been employed very effectively by Shell[1] and Standard of California[2], using Ba140-Amberol and Co60-naphthenate, respectively, as the non-volatile tracers, and gamma ray counting either *in situ* or on samples. This technique has also been employed by Shell for the measurement of entrainment in

aqueous vacuum distillation pilot plant units, using P32-phosphoric acid as the non-volatile tracer, and liquid scintillation counting. Entrainment of as little as 0.001 per cent. of bottoms is readily measured.

Proper Mixing Vital

Mixing is of great importance in refinery and chemical manufacturing operations. Inadequate mixing of materials usually leads to inferior products; more than adequate mixing results in reduced throughput and excessive power costs. Mixing of two thermal cracking feed stocks in a 50,000-barrel surge tank has been studied by Standard of California[3], using a Zr95 chelate compound as the tracer and external continuous measurement of the Zr95 gamma rays. Standard of California[4,5] has also studied the uniformity of distribution of liquid reflux in a large bubble cap tray vacuum distillation column, employing Sb124-triphenylstibine as the non-volatile tracer and external continuous counting of the Sb124 gamma rays.

Shell has studied the mixing patterns of air in a refinery fluid catalytic cracking unit regenerator (with Kr85 as the air tracer and ion chamber measurement of samples), the distribution pattern of liquids in a small trickle-phase reactor (with H3-labelled hydrocarbon and liquid scintillation counting of samples), and the mixing patterns of cracking catalyst in various refinery fluid catalytic cracking units[6,7]. In the cat cracker studies detailed mixing patterns were observable in units containing as much as 900 tons of catalyst, while only using 0.5 millicuries of tagged catalyst (Sc46)—due to the high efficiency scintillation counter method employed to count the samples. In these studies, the rate of decline of surface area of fresh catalyst with time[8], the rate of loss of fresh catalyst as fines out the regenerator stack[9], and the total catalyst inventory in the unit were also determined.

Tracers and Lubrication

In some of the studies the surface area decline rate and stack loss rate of two or three different fresh catalysts, each labelled with a different radioisotope (Ce144, Cr51, Sc46) were studied simultaneously, employing a gamma ray spectrometer to distinguish amongst the various gamma emitters[10,11,12]. Rather similar fluid cracking catalyst studies have been carried out by the Texas Company[13] (mixing and stack loss, using Co60-tagged catalyst), and Standard of California[14] (stack loss, using Cs134- and Co60-labelled catalysts).

Veering away from refinery applications now, it is of interest to note the extensive radiotracer work carried out in the petroleum industry on the subjects of lubrication and fuel combustion. Starting from the first work on piston ring wear with radioactive rings, by Atlantic Refining[15], many other companies have utilized this technique, *e.g.*, Standard of California[16], Shell[17], Southwest Research Institute[18], Sinclair[19], Phillips[20] and Ethyl[21]. Similar wear studies have been carried out with steel ball bearings[22], Babbitt metal bearings (Standard of California)[23], valves (Esso)[24], gears (Shell)[25] and cylinder liners (Esso-England[26] and Shell[27]). In some cases the wear rates of two moving parts, each radioactive, are studied simultaneously, using a gamma ray spectrometer (Shell)[27,28,29] or of two surfaces of the same moving part (Ethyl)[30]. The Shell studies involve use of an activated steel cylinder liner (Fe59) with an activated chrome-plated piston ring (Cr51). The Ethyl studies involve use of an activated chrome-plated ring, with simultaneous measurement of the chrome face wear (Cr51) and the iron side wear (Fe59). In most of these wear studies, the lubricating oil is circulated continuously through a counting cell in which a scintillation counter (or in some cases a Geiger counter) is immersed, and the output is fed to a ratemeter and strip-chart recorder. The gear studies at Shell also involve measurement of metal transfer from radioactive gear to non-radioactive gear by autoradiography of gear tooth surfaces of the latter.

Oil Consumption

Studies have also been carried out at Shell on the mechanism of action of extreme pressure additives to lubricating oils, employing S35-labelled EP additives, followed by counting and autoradiographing of gear tooth surfaces[31]. Another study of a different type is that carried out at Shell for the measurement of oil consumption rates in operating engines using tritium-labelled lube oil, and liquid scintillation counting of exhaust water samples[32]. Combustion chamber deposit formation has been studied by Du Pont[33] (using Pb210-tetraethyl lead) and by Esso[34] (using C14-labelled hydrocarbons of various types).

The above-mentioned studies have only briefly summarized the kinds of radiotracer work carried out by the petroleum refining and petrochemical industry in but a few areas out of the many areas in which research is active. Extensive uses in analytical chemistry, corrosion studies, reaction mechanism studies, and in instruments using radioactive sources have been excluded. This restriction has been made because of limitations of space, but it is hoped that these will serve to illustrate the variety and scope of radiotracer work in the petroleum industry. The applications employed usually served to (1) provide information not otherwise obtainable, or (2) provide information in a manner that is more accurate, faster, or less expensive than by other methods.

A good deal of the work described has been done with some of the older techniques—such as Geiger counting, ionization chamber measurement, and autoradiography. Many new applications are still possible with these older techniques, but even more interesting possibilities of applications exist with the as yet less exploited methods of crystal, plastic, and liquid scintillation counting, gamma ray spectrometry, gamma milking, recoil and gas exposure labelling, activation analysis, and tracer chromatography.

The Better Method

In particular, the scintillation counting methods will detect so much lower concentrations of radioisotopes than will Geiger counting methods that the safety aspects are greatly simplified, since less radioactivity need be used in any given problem. Also, very large scale tracer studies are quite feasible, with very modest amounts of radioactivity, when scintillation counting is employed. For example, 1 millicurie of a typical gamma emitter can be diluted with as much as 2,900,000 gal of water or hydrocarbon, and still be accurately detected by NaI scintillation dip counting[35]. Similarly, 1 millicurie of tritium-labelled material can be diluted with as much as 82,000 gal of hydrocarbon, and still be accurately detected by liquid scintillation counting[36]. For 1 millicurie of C14-labelled material the corresponding possible dilution is 390,000 gal of hydrocarbon[37]. In the case of tritium water, 1 millicurie may be diluted with as much as 1,200 gal of water and still be accurately measured by the ionization chamber method[38], or with as much as 3,100 gal if the liquid scintillation method is used. Fortunately, tritium water is relatively innocuous and inexpensive, so large quantities can be used, with correspondingly larger dilutions.

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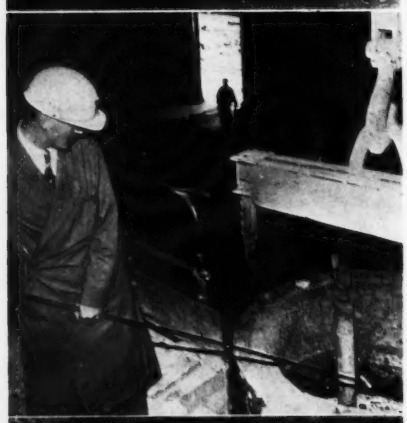
Unpacking the aluminium container holding the tantalum radioisotopes

The small vessel holding the radioisotope is moved with the aid of 3 ft tongs to a larger container, also of aluminium, with a screwed top



The tantalum is added to the molten steel

Checking the radioactivity of steel ingots "branded" with radioactive tantalum

Keeping Track of Steel Casts

THE use of radioisotopes for the identification of steel castings was made by Sandviken Jernverks AB in the production of tubes for two heat exchangers for Sweden's first commercial nuclear power/heat plant, which is being erected at Farsta, south of Stockholm.

To obtain a guarantee against confusion of material during the long chain of manufacture AB Atomenergi, official contractors to the Swedish Atom Energy Board, for whom the plant is being built, prescribed that the completed tubes should either be subjected to 100 per cent. analysis control or, alternatively, that isotope branding should be used during the process of manufacture. As 100 per cent. analysis control (*e.g.*, spectroscopic, magnetic or chemical) would be impractical. Sandviken chose the method of isotope branding.

In consequence, to each melt of 4.5 tons about 5 gm of a radioactive tantalum isotope was added in the ladle during casting. The isotope, which is kept in an aluminium container, is transferred into the cast by 3 ft tongs.

The processing of the eight melts of the isotope branded steel cast so far has gone according to plan. Radiation from the ingots is of sufficient strength to permit identification of the tubes after nine months. On the other hand, the intensity of radiation from the ingots is so low that no special precautions have to be observed in the handling of the material during the rolling and other operations.

This method of branding, which saves a considerable amount of time and money, is also of practical interest in the production of high-pressure tubes for superheaters and steam-power plants.

BOOK REVIEW

Principles of Radioisotope Methodology, by Grafton D. Chase. Published by Burgess Publishing Co., Minneapolis. (In United Kingdom available from Mayflower Publishing Co., Ltd.) 286 pp. Price 48*s*.

"Principles of Radioisotope Methodology" is based upon a series of lectures and a practical course at the Philadelphia College of Pharmacy and Science. The book is primarily intended as a laboratory manual for the technician and newcomer to radioisotope techniques. Much useful information is contained within the pages but it is rather unfortunate that the presentation of this information is so closely tied to one particular laboratory.

The general layout of the volume consists of a series of laboratory notes of experiments taken from a practical course, each section being preceded by a short introductory lecture. Many sections contain somewhat spacious blank tables for the presentation of results, apart from the column headings; their value is questionable in a bound volume. The academic level of the various sections is rather mixed, ranging from very elementary to considerably higher standards. Each chapter includes a list of topic headings entitled "Lecture outline and study guide"—it is assumed that such a lecture series would be presented in parallel with the practical course.

The opening sections on Geiger-Muller counters, sample preparation and basic criteria for radiation measurement constitute a fairly elementary introduction. The third chapter on radioactive decay is useful and is followed by a very good chapter on the often misunderstood subject of statistics. The fifth chapter deals with the properties of radiations and their interaction with matter; the background knowledge assumed is rather varied throughout this chapter. Chapter six briefly describes the methods of standardization of radioisotopes and describes some experiments by which unknown amounts of activity may be calibrated (not standardized).

The list of available standardized radioisotopes is restricted to U.S. supplies. The next chapter is entitled "Instrumentation" and adequately describes gas-filled counters and scintillation counters. It is unfortunate that the experiments described in this chapter refer to specific pieces of equipment and are therefore of restricted use to general readers.

The book now turns to chemical problems. The academic level is fairly elementary again in this chapter and the experimental descriptions are quite lengthy. The last chapter, which is on biological applications, is naturally of limited interest. The early part of the chapter is chemical in nature and the tracer technique receives its first mention. *In vivo* and *in vitro* experiments on animals are described, followed by a section on the important topic of autoradiography. Nine appendices listing definitions, some problems and mathematical tables, followed by an index complete the book.

For readers beginning radioisotope work and for those attending an isotope course, this book could be very useful though it is doubtful whether experienced workers would derive great benefits from it.

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Tracers used in Soviet Plant Physiology

Among research workers who have made good use of radioisotopes ever since they were introduced have been the biologists. This article describes some of the work undertaken by Russian scientists in tackling the problems of metal plant metabolism and reproduction by using these new and important "tools"

AGRICULTURAL chemicals will be most efficiently employed when there is a thorough understanding of the various biochemical processes in which these chemicals are to take part; otherwise, the application of the industrial products must rest on rule-of-thumb methods. Chemicals of various types are finding increased application in the improvement of plants, whether food crops, forestry trees, plants for decoration, or plants producing fibres or other useful materials for man's protection or other form of benefit.

Every plant is a marvel of chemical processing, and the understanding of even the simplest process in any one plant species has not yet been completely achieved. Modern techniques, however, are gradually unravelling the mysteries of plant physiology, and we are slowly coming to appreciate the stages that occur in photosynthesis, plant growth and nutrition, the application of fertilizers, growth hormones, systemic poisons, flowing and fruiting control agents and so on.

U.S.S.R. Not Slow

One of the most useful tools which has been put into the hands of the plant research worker is the radioisotope. By mixing small quantities of a radioactive isotope with the stable material the scientists can follow the course of the material in all chemical and biological processes, the radioactivity of the unstable atoms acting as a marker for the inactive ones. This is the "tracer" technique, of which so much use has been made of recent years in all scientific fields.

The U.S.S.R. has not been slow to apply tracer methods to the many problems which face the plant physiologist and agronomist, and this article aims to point out just a few ways in which Soviet scientists have tackled these difficult tasks.

One of the problems tackled has been the question of the renewal of chlorophyll and protein molecules in plant life. It was suspected as early as the last century that chlorophyll, the green pigment which plants use in their photosynthesis of carbon dioxide and water into foodstuffs, could be renewed during the normal life of the plant.

Soviet workers have shown that radioactive carbon-14 can be incorporated into chlorophyll and the carotinoids (yellow pigments also concerned with photosynthesis) on short exposure of the plant to carbon dioxide in which there is radioactive carbon. A. A. Shlyk and T. N. Godnev subjected chlorophyll and carotinoids labelled with C14 to a special chromatographic separation and proved that the C14 in the pigments was not the result of impurities.

13-Day Renewal

The period of semi-renewal of chlorophyll proved to be about 13 days in mature tobacco leaves. F. V. Turchin showed that the semi-renewal of the nitrogen in chlorophyll took three or four days for young plants of oat, barley and rye. This difference results from peculiarities in metabolism, age and ecology.

It was established that the large phorbin and phytol portions of the chlorophyll molecule were not used again, but that renewal involves a decay of old chlorophyll molecules and complete resynthesis of new ones. The rate of renewal of nitrogen in protein was of the same order as for that in the chlorophylls, namely three days.

In the dark, chlorophyll breakdown occurs, but there is no renewal. The two chlorophyll components are not converted into one another rapidly, and the splitting of the chlorophyll molecule into phytol and phorbin and the determination of their radioactivity proved that the chlorophyll A and chlorophyll B are only capable of slow exchange with phytol.

Chlorophylls Separate

Chlorophyll B cannot be a predecessor of chlorophyll A, and independent biosynthesis is also impossible. This means that both chlorophylls are formed from a common ancestor.

Further work seemed to indicate that the formation of chlorophyll B was not in parallel with that of the chlorophyll A, but occurred through it. The chlorophyll phytol is not the predecessor of the carotinoids, and both pigment groups are not subjected to the rapid reciprocal transformations which might be expected if this system is directly involved in photosynthesis.

Tracer techniques have also enabled research workers to study the photosynthetic changes which occur in carbon compounds under various conditions as the carbon is assimilated partly as carbohydrates and partly as phospho-enolpyruvic acid and pyruvic acid via phosphoglyceric acid. The latter mechanism leads to the formation of malic acid, and also of amino acids such as serine and alanine, which are the precursors of the proteins.

Greater light intensity and longer wavelengths favour the formation of carbohydrates. When abundant nitrogenous foodstuffs are available to the plant, and when short wavelengths of light predominate, rapidly growing young plants show a preference for the second carbon transformation, with formation of more amino-acids and proteins.

Acids Formed

A. A. Nichiporovich, T. F. Andreyevna and N. P. Voskresenskaya have also proved that in feeble light the Krebs' cycle is not completely blocked, and the acids involved in this cycle, together with certain amino-acids, are formed. Among the latter glutamic acid predominates.

In autoradiography, plant leaves pressed on to a photographic plate will produce a photographic image of the leaf, at least of those parts of the plant in which are concentrated the radioactive elements.

In a modified method, introduced by Z. A. Medvedev, the leaf is applied under very high pressure to a filter paper block. The sap is squeezed out from the leaf, and examination of the various sheets of filter paper in the block gives an idea of differences in activity or concentration of radioactive elements in the leaf, and the information is even more extensive when selected solvents are applied. For example, trichloracetic acid will leave only the protcins and nucleic acids.

Protein Research

Filter papers impregnated with various precipitating agents may also be valuable. Such autoradiographic methods have been used to study the synthesis of proteins and nucleic acids in plants. In the haricot bean, for example, it has been shown that the proteins of the conductivity system are most rapidly synthesized, and that certain moieties of protein molecules can pass through the phloem or bast without being converted into amino-acids.

R. D. Galtsova and N. A. Pomoshnikova, in an effort to elucidate the mechanisms of the synthesis of proteins in plants, applied radiotracers to metabolism in yeasts, coupling this with chromatographic analytical methods. A quantitative estimation of pantothenic acid and pyridoxine was combined with a study of the rate at which phosphorus-32 penetrated indicator cultures. It was proved that vitamins and amino-acids have an important influence on the biosynthesis of sulphur-containing amino-acids and the introduction of these into the molecules of proteins.

Vitamins' Role

The addition of pyridoxine to a certain culture medium containing labelled sulphate resulted in an increase by 25 per cent. in the radioactivity appearing in the plant, while the latter was increased by 15 per cent. by an addition of thiamine or inositol to the medium. Biotin and nicotine acid produced no effects on sulphur uptake, while pantothenic acid actually reduced the uptake of sulphur-35.

Simultaneous addition of pyridoxine, biotin and thiamine resulted in a 35 per cent. increase in radioactivity of the protein. A 25 per cent. increase resulted from the presence of asparagine or aspartic acid, glumatic acid produced no effect, and alanine increased S35 absorption by 15 per cent.

Although it may be argued that results obtained with yeasts cannot be extrapolated to the higher plants, the value of the techniques cannot be disputed. This work has shown beyond all doubt that vitamins and certain amino-acids may play a vital role in protein synthesis, a fact which may prove equally important in the question of the nutrition of higher plants.

Use of C14

In a related field of research, E. Y. Veselov, N. V. Pokronoskaya, S. S. Rylkin and V. N. Shil, using radioactive C14, have established the presence of lactic, pyruvic, acetic, amino-acetic and other amino-acids, together with glucose, acetaldehyde and carbon dioxide, among the products of autolysis of yeasts. It appears that there is not a simple equilibrium between carbohydrates of the medium and those in the yeast, but that hydrolysis products and other intermediates enter into the equilibrium.

Radioactive hydrocarbons in the medium become converted into radioactive intermediates which are in equilibrium with both radioactive and inactive components in the medium. Inactive amino-acids in the medium take part, together with intermediate products derived from the carbohydrates, in re-amination and re-carboxylation processes, with formation of both radioactive and inactive amino-acids in the plant.

Labelling Amino Acids

When labelled glucose is fermented in a medium containing non-radioactive amino-acids, the activity of the amino-acids in the yeast reaches at least 50 per cent. of that of the glucose. When lactic, pyruvic and acetic acids, and acetaldehyde are the

labelled components of the fermentation medium, the amino-acids in the yeast become labelled.

Higher alcohols can result not only from deamination and decarboxylation of the type $R.NH_2COOH = NH_3 + CO_2 + ROH$, but also from a more complex reaction involving intermediates in the carbohydrate fermentation. When only labelled glucose is added to the medium, radioactive carbon appears in the higher alcohols. Secondary products, such as ethers, are not formed by a reaction such as alcohol + acid = ether + water, but as the result of the reaction aldehyde + aldehyde = ethers.

Fertilization Studies

Intermediate products such as aldehydes, by a sort of Cannizzaro reaction, can give rise to acids, which are then important in the biosynthesis of proteins, amino-acids and fats. Carbon dioxide fixation is also important, and takes part in protein synthesis.

Even the question of fertilization in plants has been tackled by means of radioactive compounds, and much interesting information has come forth from this work. I. M. Polyakov, A. N. Dmitrieva and A. F. Zdrilko studied fertilization in tobacco, maize, cotton and peas, by making use of pollen labelled with radioactive sulphur, S35, and radioactive phosphorus, P32.

When they applied non-radioactive pollen to a plant, followed by labelled pollen, the latter introduced radioactivity into the seeds even though the first pollination had proved effective in fertilization. Quantitative results could be obtained from a knowledge of the activity per unit weight of pollen, the number of pollen grains per unit mass, the activity of unit mass of the seeds, and the number of seeds in unit mass. Thus, it was possible to calculate from what quantity of pollen tubes the labelled phosphorus and sulphur passed into a single seed. In the case of maize, this proved to lie between 3.2 and 8.3 per seed.

Over 70 per cent. of the radioisotope from pollen in repeated pollinations is found in embryos and endosperm, and these elements, entering into complex molecules from the pollen, are transferred to the ovary, and become incorporated into the ovary by methods not involving the pollen tubes. The placenta behaves as a sort of reservoir, collecting the compounds donated by the pollen tubes, and redistributing them among the seeds. Such methods have been used to study the interaction of the pollen of different species and pollen mixtures used in distant hybridization.

Plant Disorders

A. M. Kuzin and V. I. Tokarskaya investigated by tracer methods some of the metabolic disturbances in plants. In an organism in a pathological state, anomalous products of metabolism may be produced. These are often impossible to detect by even fairly sensitive methods such as chromatography. However, if all the organic substances in the plant can be labelled with radioactive atoms, radiochromatography can be used to follow the metabolites, especially if ultra-violet fluorescent detection methods are also used.

Prolonged exposure of the plant to an atmosphere containing radiocarbon, C14, say for 25 days, results in transfer of radioactivity to all the primary photosynthetic products, pigments such as chlorophyll, and alkaloids such as nicotine, morphine and atropine. It is possible to study the kinetics of the formation of organic substances in the roots of the plants, this formation being sharply increased by irradiation.

Intermediates Formed

In irradiated plants there were eight organic intermediates formed which are absent from plants which have not been irradiated. This, of course, is a factor which needs to be watched carefully in such experimental work, since it has often been assumed that the irradiation of plants will not produce any anomalous metabolic changes.

To those concerned with the use of fertilizers, the root of the plant cannot fail to be of great interest, and A. L. Kursanov has made a deep study of the root system as a metabolic organ. Neglect of this system in the past has impeded seriously a proper understanding of the mechanisms of absorption and primary assimilation of ions.

At certain stages in the life of a plant, up to 50 per cent. of an assimilated material labelled with radioactive carbon is directed from the leaves to the roots. The descending material consists of sucrose largely, synthesized in the conducting system. Amino-acids and other organic acids do not form a significant part of the substances passing downwards.

The presence of nitrites in the neighbourhood of the roots causes a sharp increase in the transport of materials from leaves to roots. In the roots, the sugars which have been passed down from the leaves are broken down into organic acids and other ionic compounds, but later there is formation of amino-acids, amides and ureides.

Marrow Root

In the root of the marrow, for example, about 30 different compounds have been identified as products from the transformation of the sugars via glycolysis and the Krebs' cycle. These products act as carbon acceptors and take part in the fixation of carbon dioxide taken in by the roots.

About 50 per cent. of the substances metabolized in the roots are carried off to other parts of the plant. These studies have established the facts that the roots are metabolic in function, effecting sugar transformations, determining the character of the primary accumulation of elements absorbed, and distributing metabolic products throughout the plant.

Forestry Work

Metabolic processes in forest trees are also of great interest, since it may prove possible, through a thorough understanding of these processes, to modify timbers to suit man's requirements, or to make better use of the by-products, or even to induce trees to form new products for our use. G. V. Sukhov, using tracer techniques, has studied the biosynthesis of terpenes and resin acids, especially in the pine, *Pinus sylvestris*.

Radioactive carbon, C14, has been introduced in the form of carbon dioxide into the crowns of trees 10 m high, and a portable photosynthetic chamber was developed to assist in this work. Studies were made of the kinetics of carbon dioxide conversion into carbohydrates, terpenes and resin acids, and of the effects of light intensity and gas concentration. This study was applied to needles, bark and wood.

Terpene Turnover

Terpenes and resin acids are not simply end-products, but are continually broken down and used again in metabolic processes. At 15°-20°C., the biological half-life of mono- and di-saccharides in pine needles is about one day, but two days in the case of dicyclic monoterpenes and resin acids, although there is a faster turnover of intermediates. The turnover rate for terpens in the needles produced in any one year is 10 times that of needles produced in the preceeding year, and is unaffected by tapping.

E. A. Shillov, again using tracers, has worked on the biosynthesis of rubber in the Kok-sagyz plant. When aqueous solutions of various compounds labelled with C14 were introduced into the plant, 50-80 per cent. of these were transformed into carbon dioxide within five or six days, and the water-soluble substances so labelled formed only 10-15 per cent. of the original by the fifth day, while 0.5-3.0 per cent. was converted into rubber resins, carotenes and cellulose.

Activities Produced

The greatest radioactivity was imparted to rubber by the 2-C atoms of alanine; less effective, though equal among themselves, were the 2-C atoms of pyruvic acid and acetone, the 1-C of acetic and glyceric acids, and the 3-C of acetoacetic acid.

Still less effective were the 1-C atoms of pyruvic acid and alanine, and the 3-C from beta-methylcrotonic acid. Carotene acquired considerable activity from the 1-C of acetic acid, and the 2-C atoms of alanine and acetone. It seems, then, that biosynthesis of rubber and carotene involves the condensation of a carbon-carbon linkage with trioses or their derivatives.

Conclusion

Cellulose acquires greatest activity from the 1-C atom of glucose, and much less from the carbon atoms of acetic, levulinic and pyroracemic acids, and alanine. Since the radioactivity of cellulose increases up to the eighth day after irradiation of the plant, and then falls again, it seems that there is participation in some new metabolic reaction.

These few examples of the application of tracer techniques will show the type of work which is going on in the Soviet Union, and which is aimed at bringing a much more scientific attitude to bear upon the many problems which beset those who are concerned with the nutrition of plants, the health of these, and the utilization and development of the products for which the plants are grown by man.

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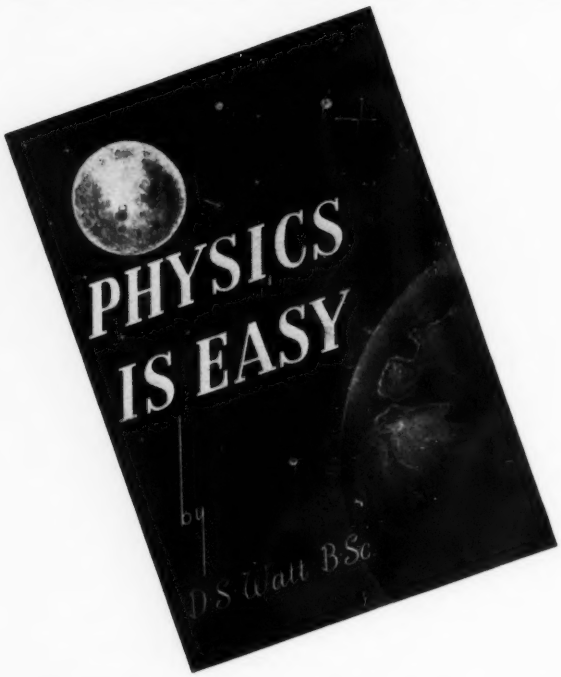

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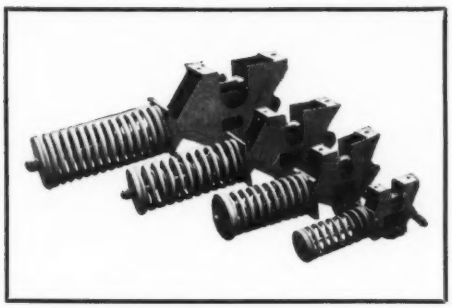

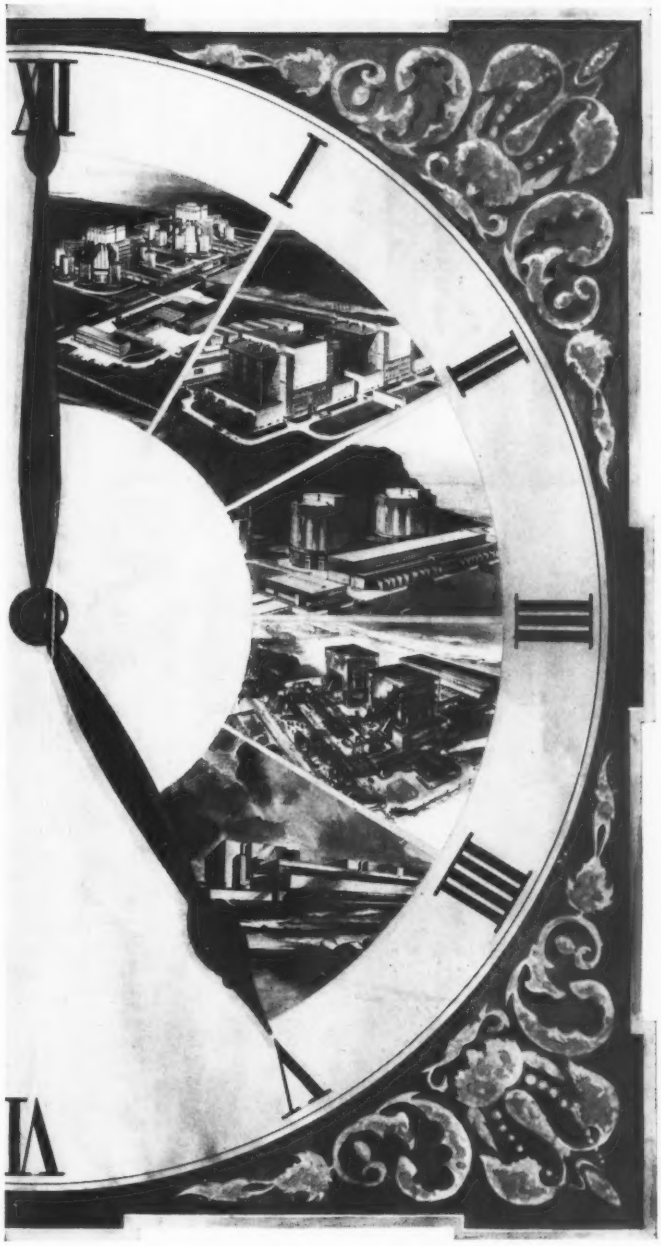

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